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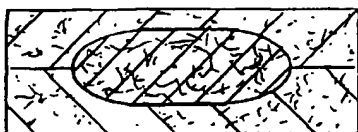
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(54) Title: **ABSORBENT CORES WITH Y-DENSITY GRADIENT**



(57) Abstract: Disclosed are absorbent structures having y-directional profile in density and superabsorbent polymer particle content. The structures include zones having higher density and higher superabsorbent polymer particle content and zones having lower density and lower superabsorbent polymer particle content. Also disclosed are methods for preparing absorbent structures having y-directional profile in density and superabsorbent polymer content.

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ABSORBENT CORES WITH Y-DENSITY GRADIENT

**Related Applications**

This application claims the benefit of U.S. Provisional Patent Application No. 60/166,489 filed November 19, 1999; U.S. Provisional Patent Application No. 60/211,090 filed June 12, 2000 and U.S. Provisional Patent Application No. 60/211,091 filed June 12, 2000, all of which are hereby incorporated by reference.

**Field of the Invention**

This invention is directed to the field of unitary absorbent structures for use in absorbent articles, in which one or more of the strata of the absorbent structure is profiled in the y-direction, in one or more of the properties of basis weight, functional particle content, or density, and processes for the production of the structure.

**Background of the Invention**

Absorbent structures are used in a wide range of disposable absorbent articles, including baby diapers, adult incontinence products, sanitary napkins and the like. These and other absorbent articles are generally provided with an absorbent structure which is disposed as a core, to receive and retain body liquids. The absorbent core is usually sandwiched between a liquid pervious topsheet, whose function is to allow the passage of fluid to the core, and a liquid impervious backsheet, whose function is to contain the fluid and to prevent it from passing through the absorbent article to the garment of the wearer of the absorbent article.

An absorbent structure which is used as a core for diapers and adult incontinence pads frequently includes fibrous batts or webs constructed of defiberized, loose, fluffed, hydrophilic, cellulosic fibers. The core may also include functional particles, such as superabsorbent polymer ("SAP") particles, granules, flakes or fibers (collectively "particles").

In recent years, market demand for an increasingly thinner and more comfortable absorbent article has increased. Such an article may be obtained by decreasing the thickness of the structure used as the diaper core, by increasing the amount of functional particles, and by calendaring or pressing the core to reduce caliper and hence, increase density.

However, higher density articles used as cores do not absorb liquid as rapidly as lower density cores, because densification of the core results in a smaller effective pore size. Accordingly, to maintain suitable liquid absorption, it is necessary to provide a low-density strata having a larger pore size above the high-density absorbent core to increase the rate of uptake of liquid discharged onto the absorbent article. The

low-density ply is typically referred to as an acquisition strata. Multiple strata absorbent core designs involve a more complicated manufacturing process.

The storage ply portion of a disposable diaper, for example, is generally formed in place, during the converting process, from loose, fluffed cellulose. Such  
5 cellulose material is generally not available in preformed sheet form because it exhibits insufficient web strength, owing to its lack of interfiber bonding or entanglement, to be unwound or unfestooned directly onto and handled in absorbent pad-making equipment. Some absorbent articles such as ultra-thin feminine napkins are generally produced from roll-goods based nonwoven material. Such a roll of preformed absorbent core material is  
10 unwound directly as feedstock into the absorbent article converting equipment without the defiberization step normally required for fluff-based products, such as diapers and incontinence pads. The nonwoven web is typically bonded or consolidated in a fashion that gives it sufficient strength to be handled during the converting process. Absorbent structures made from such nonwoven webs may also contain SAP particles. However,  
15 these absorbent structures are often inefficient in cases where a demand is for acquisition and absorption of high amounts or a surge of body fluids. In these cases, a single ply absorbent material often is not sufficient to serve as the absorbent core because the liquid is not distributed in the structure along the length of the absorbent core. As a result, regions of the absorbent core remain unused. The web consolidation  
20 mechanism used in the roll-goods approach to making preformed cores provides strength and dimensional stability to the web. Such mechanisms include latex bonding, bonding with thermoplastic or bicomponent fibers or thermoplastic powders, hydroentanglement, needlepunching, carding or the like. However, such bonded materials provide a relatively

stiff core which often does not conform well to the shape of the human body, especially in those situations where there is a demand for good fit to acquire and contain high volumes of body fluids.

Pliability and softness of the absorbent core are necessary to ensure that the  
5 absorbent core can easily conform itself to the shape of the human body or to the shape of a component, for example, another absorbent strata, of the absorbent article adjacent to it. This in turn prevents the formation of gaps and channels between the absorbent article and the human body or between various parts of the absorbent article, which might otherwise cause undesired leaks in the absorbent article.

10 Integrity of the absorbent structure used as a core is necessary to ensure that the absorbent core does not deform and exhibit discontinuities during its use by a consumer. Such deformations and discontinuities can lead to a decrease in overall absorbency and capacity, and an increase in undesired leakage. Prior absorbent structures have been deficient in one or more of pliability, integrity, profiled absorbency and  
15 capacity. For example, a conventional fluff pulp core has good conformability because of its high pliability and softness but at the same time it may disintegrate easily during use, due to its poor integrity. As another example, certain bonded cores, such as airlaid cores made from cellulose fluff pulp densified to a density greater than 0.35 g/cc have dry integrity, but have no wet integrity and poor conformability.

20 Absorbent structures having improved softness and pliability have been described in U.S. Patent Application Serial No. 09/475,850, filed December 30, 1999. However, there is still a need to enhance even more the capacity of such structures by

incorporating high amounts of SAP particles and, at the same time, with maintaining high fluid acquisition efficiency of such structures.

Absorbent structures made from nonwoven webs may contain SAP particles to obtain sufficient absorbent capacity. However, there are practical limits to increasing the proportion of SAP particles in currently available commercial absorbent structure. If the concentration of SAP particles in an absorbent structure used as a core is too high, gel blocking can result and the rate of acquiring and redistributing the liquid within the core will become too slow for satisfactory performance of the absorbent core. As adjacent SAP particles swell, they form a barrier to free liquid not immediately absorbed by the SAP particles. As a result, access by the liquid to unexposed SAP particles may be blocked by the swollen, gelled SAP particles. When gel blocking occurs, liquid pooling, as opposed to absorption, takes place in the core. As a result, large portions of the core remain unused, and failure (leaking) of the absorbent core can occur. Gel blocking caused by high concentrations of SAP particles results in reduced core permeability, or fluid flow, particularly under pressures encountered during use of the absorbent product.

One way to minimize gel blocking and maintain core permeability for efficient fluid intake and redistribution is to limit the proportion of SAP particles to matrix fibers in the absorbent structure used as the core. In this way, there is sufficient separation between particles, such that even after the particles have been swollen by exposure to liquid they do not contact adjacent particles and free liquid can migrate to unexposed SAP particles. Unfortunately, limiting the concentration of SAP particles in the absorbent core also limits the extent to which the core can be made thinner and more comfortable. To

avoid gel blocking, commercial absorbent cores are presently limited to SAP particle concentrations of 20 percent to 50 percent by weight of the core. However, even with this limit of SAP particle concentration, these absorbent cores have poor fluid acquisition rates.

The absorbent structures used as cores in current commercial disposable, absorbent articles are constructed by combining several plies of material at the converting line. Typically, these multi-ply absorbent cores contain one or more plies of varying width, wherein at least one of the ply in the absorbent core is narrower than the full width of the core. The narrow ply are present in these commercial absorbent cores to improve performance and reduce raw-material costs by targeting absorbent material where it is most needed, and removing material where it is not needed. The existing art for the manufacture of absorbent cores which are profiled in basis weight involves merging several plies or structures of absorbent material at the converting line to manufacture layered absorbent cores.

Typical airlaid forming units for the manufacture of absorbent structures to be used as cores contain mechanical equipment on one side of the full width forming wire designed to accept air-suspended absorbent material and uniformly distribute the absorbent material onto the forming wire. Typically, located on the other side of the forming wire, and working in concert with the distributing equipment, is a vacuum system that is present to collect the air-suspended absorbent material onto the forming wire.

20

### **Summary of the Invention**

It would be highly desirable to provide an absorbent structure to be used as a core, which is capable of bearing a SAP particle concentration of about 10 percent to 80



percent by weight, preferably about 30 percent to 80 percent by weight, while maintaining fast fluid acquisition rate and stability of the core. It would also be desirable to provide a wet-stable absorbent core, which exhibits improved fluid acquisition and storage efficiency for a given SAP concentration.

5                   The present invention provides for an increase in converting efficiencies by using unitary absorbent structures comprising several strata of absorbent material. Applicants have now discovered a method of simplifying the manufacture of absorbent products containing profiled absorbent cores. In a first embodiment, a profiled core can be obtained by use of a forming surface which can be blocked physically with a mask to  
10                   prevent absorbent material from being deposited in specific zones, resulting in the formation of an absorbent structure with profiled strata. In an alternative embodiment, a profiled structure can be obtained by controlling the vacuum system by use of a block for the vacuum system. The block can be placed in the airlaid forming unit operation between the vacuum system and the forming wire.

15                   One object of the invention is to provide a unitary absorbent core comprising one or more strata of absorbent material, in which one or more of the properties of basis weight, functional particle content, or density of at least one of the strata is profiled in the y-direction.

                  Another object of the invention is to provide a process for manufacturing  
20                   unitary absorbent cores comprising one or more strata in which one or more of the basis weight, functional particle content, or density of at least one of the strata is profiled in the y-direction.

                  It is a further object of the invention to increase converting efficiencies by

producing unitary absorbent cores via the airlaid process versus producing multi-ply absorbent cores at the converting line by merging several absorbent materials.

Another object of the invention is to introduce y-direction density gradients into unitary absorbent cores.

5           An additional object of the invention is to provide for greater control over the attributes of unitary absorbent cores, thus providing product developers with greater flexibility.

          Further objects of the invention are to improve product performance by placing absorbent material in unitary absorbent cores where it is most effective, or  
10       removing absorbent material in unitary absorbent cores where it is not effective.

          Another object of the invention is to form absorbent cores having improved fluid acquisition and containment, as well as reduced leak potential.

          It is a further object of the invention to simplify the final product converting processes by reducing the number of plies in the absorbent structure.

15           In a first embodiment, the present invention is directed to absorbent structures having a y-directional, profile comprising one stratum or a plurality of strata, at least one stratum of which is produced by a continuous series of unit operations and which contains functional particles and has a y-directional profile. The stratum produced by a continuous series of unit operations comprises first and second zones disposed in contact  
20       with each other, wherein the first zone has one or more of a higher density, a higher content of functional particles and a higher basis weight than the second zone.

          In a second embodiment, the present invention is directed to absorbent

structures comprising functional particles and having a fluid storage and acquisition efficiency (FASE), as defined herein, of higher than about 50. In this embodiment, the structure has a y-directional profile, and comprises one stratum or a plurality of strata, wherein at least one stratum comprises first and second zones disposed in contact with each other, wherein the first zone has one or more of a higher density, a higher content of functional particles and a higher basis weight than the second zone.

In further embodiments of the first and second embodiments, the invention is directed to structures having a first zone having a higher density and a higher basis weight than the second zone, or structures having a higher density and functional particle content than the second zone. In certain embodiments, the first zone is disposed at the side edge of the absorbent structure. In additional embodiments, the structures comprise third and fourth zones, wherein the third zone has a higher density and higher content of functional particles than the second and the fourth zones.

In particular embodiments of the structures described above, the structure comprises a plurality of strata, wherein at least one stratum has a major surface area which is less than 80 per cent of the surface area of a corresponding major surface of another stratum.

In certain embodiments, the y-directional profile of the structures of the invention may be the result of a single strata having a y-directional profile, or the y-directional profile may be the result of a plurality of strata having a y-directional profile. Further, at least one of the stratum may be of substantially uniform density or basis weight.

In particular embodiments, the structure may also have a z-directional profile.

In the embodiments described above, the structures may comprise fibers, both natural and/or synthetic fibers. Suitable fibers include fibers having a water retention value of at least 80 per cent, and fibers having a curl of at least 25 per cent.

In the embodiments described above, the structures may comprise a binder, including a liquid binder (such as a latex binder), thermoplastic powders, thermoplastic fibers, bicomponent fibers and mixtures thereof. The binder may, for example, be present in the amount of about 0.1 percent to about 10 per cent of the structure.

The invention is also directed to the above embodiments, further comprising an acquisition stratum in fluid communication with the first zone, the second zone, or with both the first zone and the second zone. The acquisition stratum may comprise synthetic matrix fibers bonded with a binder, wherein the matrix fibers may have a length of from about 2 to about 15 mm.

In any of the above embodiments, the basis weight of the first zone is from about 50 gsm to about 1000 gsm. The basis weight of the second zone may be from about 0.1 gsm to about 800 gsm.

In certain aspects of the invention, the density of the first zone may be from about 0.15 g/cm<sup>3</sup> to about 0.25 g/cm<sup>3</sup>.

Additionally, in certain aspects of the invention the functional particle content in the first zone may be about 10 per cent to about 90 per cent by weight, and/or the functional particle content in the second zone may be about 0 per cent to about 70 per cent by weight.

In particular embodiments of the structures described above, the FASE

value is higher than about 80. The structure may also have a wet integrity higher than about 4.0 mN/gm, a softness higher than about 8.0/J, or a pliability higher than about 70/N.

In particular embodiments of the structures described above, the structure is  
5 produced by a continuous series of unit operations, wherein each stratum is formed in one unit operation from one or more materials selected from fibers, functional particles, binders, carrier tissue and additives.

The present invention is also directed to disposable absorbent articles comprising:

- 10 (A) a liquid pervious topsheet,
- (B) a liquid impervious backsheet,
- (C) between the topsheet and the backsheet and in fluid communication with the topsheet an absorbent structure as described above, the structure comprising one stratum or a plurality of strata, at least one stratum containing functional particles, the absorbent  
15 structure having a y-directional profile comprising first and second zones disposed in contact with each other, wherein the first zone has one or more of a higher density, a higher content of functional particles and a higher basis weight than the second zone, and, optionally,
- (D) between (C) and (B) and in fluid communication with (C) a storage stratum  
20 comprising fibers and functional particles where a major surface of (C) in fluid communication with a major surface of (D) has a surface area which is less than 80 percent of the surface area of a corresponding major surface of (D).

In particular embodiments, the absorbent structure (C) may comprise

- (1) a y-directionally profiled acquisition stratum; and
- (2) a y-directionally profiled acquisition and storage stratum having a higher content of functional particles than that of the acquisition stratum.

The articles described above may be infant diapers, training pants, adult  
5 incontinence devices, or feminine hygiene pads. In particular embodiments, the articles of the invention may have a FASE of 50 or higher, preferably 80 or higher, more preferably 100 or higher.

In certain aspects, the structures of the present invention can be manufactured by suspending absorbent material in a fluid and depositing the material on a  
10 porous forming surface, or forming wire. The suspending fluid for the absorbent material can be water or air, but preferably is air. Placing several forming unit operations in series provides for the formation of unitary absorbent structures comprising several strata of absorbent material.

Typical airlaid forming unit operations contain mechanical equipment on  
15 one side of the forming wire designed to accept air-suspended absorbent material and uniformly distribute the absorbent material onto the forming wire. Typically located on the other side of the forming wire, and working in concert with the distributing equipment, is a vacuum system that is present to collect the air-suspended absorbent material onto the forming wire. The present invention provides for reducing the vacuum in specific zones in  
20 the y-direction, such that one or more of the properties of basis weight, density or SAP content of the absorbent material collected on the forming wire is profiled.

In a preferred embodiment of the invention, the vacuum used to collect air-suspended absorbent material is blocked, essentially reducing the vacuum to zero in

specific zones in the CD. When the vacuum is blocked in specific zones, the striped strata of the present invention can be formed.

In another preferred embodiment of the invention, the distribution of air-suspended absorbent material is physically blocked in certain areas, so as to cause  
5 deposition on the forming wire which is profiled in the cross-machine direction and the striped strata of the present invention can be formed.

This invention provides a process for the production of an absorbent structure comprising a plurality of strata, at least one stratum of which is produced by a series of unit operations and which contains functional particles and has a y-directional  
10 profile comprising first and second zones disposed in contact with each other, wherein the first zone has one or more of a higher density, higher content of functional particles or higher basis weight than the second zone, the process comprising:

- (1) forming a first stratum A comprising fibers and, optionally, functional particles;
- 15 (2a) forming a second stratum B comprising fibers and functional particles such that a major surface of B is in fluid communicating contact with a major surface of A and the y-directional length of B is less than the y-directional length of A; or
- (2b) forming a second stratum B comprising fibers and functional particles such that first and second zones disposed in contact with each other are formed, wherein the  
20 first zone has a higher density and a higher content of functional particles than the second zone.

In particular embodiments of the process described above, strata are formed

on a forming wire of an airlaid process from fibers and functional particles distributed from a forming head and the first and second zones of stratum B are formed by partially blocking distribution into the second zone but not the first zone.

In an alternative embodiment of the process of the invention, strata are  
5 formed on a forming wire of an airlaid process from fibers and functional particles distributed from a forming head and the first and second zones of stratum B are formed by partially blocking distribution into the second zone but not the first zone.

The invention is also directed to absorbent structures made by the process described above.

#### 10 **Brief Description of the Drawings**

Fig. 1 depicts a unitary absorbent structure on a forming wire, and depicts the x-direction, y-direction and z-direction in relation to the structure;

Fig. 2a depicts a prior art unitary absorbent structure;

Fig. 2b depicts a unitary absorbent structure of the invention;

15 Fig. 2c depicts a unitary absorbent structure of the invention;

Fig. 3 depicts an absorbent structure of the invention having y-directional structural profile of density and SAP content;

Figs. 4a-4i depict unitary absorbent structures of the invention with three strata, including striped strata;

20 Fig. 5a-5d depict additional embodiments of unitary absorbent structures of the invention;



Fig. 6 depicts an absorbent structure of the invention composed of two strata, wherein the upper strata has y-directional structural profile of density and SAP content;

Fig. 7 depicts an absorbent structure of the invention composed of two strata,  
5 wherein the lower strata has a y-directional structural profile of density and SAP content;

Fig. 8 depicts a process of making an absorbent structure according to the present invention;

Fig. 9 depicts a closeup view of the forming wire of Fig. 8;

Fig. 10 is a view along the direction A to B of the forming wire of Fig. 9;

10 Figs. 11A and 11B depict a tester used to test absorbency properties of absorbent structures of the present invention;

Fig. 12 depicts a Gurley Stiffness Tester used to measure the pliability of absorbent structures of the invention;

15 Figs. 13A and 13B depicts a clamp used to measure the pliability of absorbent structures of the invention;

Figs. 14A-14C depict basis weight profiles of Samples A through C;

Fig. 15 depicts y-direction basis weight profiles for Samples A through C.;

Fig. 16 depicts y-direction density profiles for Samples A through C;

Figs. 17A and 17B depict schematic drawings for Samples D and E;

20 Figs. 18A and 18B depict schematic drawings for Samples F and G; and

Fig. 19 graphs the rewet properties as a function of the bottom stratum basis weight and width for Samples H and J.

**Detailed Description of the Invention**

All patents and patent applications cited in this specification are hereby incorporated by reference into this specification. In case of conflict in terminology, the present disclosure controls.

**5 Definitions**

As used herein, the term "stratum" and in the plural "strata" means the output of a unit operation designed to place absorbent material on the forming surface, which may employ a carrier tissue, or wire of a forming process. The process can be wetlaid or airlaid, but preferably is airlaid. Materials deposited on the forming surface by the unit operation  
10 include fibers, powders including additives and functional particles, such as SAP and binders. The totality of materials deposited on the forming surface may be referred to as a "web" which grows during the forming process as a successive unit operations add to the web.

As used herein, the term "profiled stratum" means a stratum in which one or more of the basis weight, density or content of functional particles (such as super absorbent  
15 polymer particles) of the stratum varies (is profiled) in the y-direction and/or the z-direction.

As used herein, the term "striped stratum" means a special case of a profiled stratum in which one or more of the absorbent material basis weight, density or content of functional particles in the stratum drop to very low levels or zero for a finite length in the y-direction. This finite length of zero basis weight, density or content of functional particles  
20 can be continuous or it can be parceled in discontinuous segments. The parceled segments can be distributed in a uniform pattern in the y-direction or there can be no uniform pattern. The finite length of very low levels or zero basis weight, density or content of functional

particles can be distributed symmetrically about the longitudinal axis of the structure or it can be distributed asymmetrically about the longitudinal axis of the structure.

As used herein, the term "ply" refers to a fibrous material which may be used as a component in an absorbent article. A unitary absorbent core is an example of a ply.

5 Other exemplary plies include a storage and acquisition layer, a liquid pervious topsheet and a liquid impervious backsheet. A series of plies may be assembled into an absorbent article in a converting process, in which plies are attached by glue or other adhesive, by thermal bonding, or by pressing or densifying the plies to produce entanglement.

As used herein, the term "content" means percentage by weight. Thus, the  
10 content of functional particles in a given stratum is the percent by weight of functional particles in that stratum.

As used herein, the term "x-direction" refers to the direction along the length of the absorbent article 1, as illustrated in Figure 1. When the web is formed so that the absorbent article is disposed on a horizontal or flat forming wire 2, the x-direction is the  
15 machine direction (MD).

As used herein, the term "y-direction" refers to the direction along the width of the absorbent article (see Figure 1). Referring to Figure 1, when the web is formed so that the fibrous material is disposed on a horizontal or flat forming wire 5, the y-direction is the cross-machine direction (CD).

20 As used herein, the term "z-direction" refers to the direction into the plane of the absorbent article (see Figure 1).

As used herein, the term "width" of a stratum is the distance from one side of the stratum to the other, measured in the y-direction normal to the longitudinal axis of the structure.

As used herein, the term "basis weight" is the weight of a web per unit area. It is usually expressed as grams per square meter ( $\text{g/m}^2$  or  $\text{gsm}$ ). Basis weight is an intensive property of a web, in that it is independent of the amount of web that is present.

As used herein, the term "density" is expressed in grams per cubic centimeter ( $\text{g/cc}$ ), and is defined according to the following equation:

$$\text{Density (g/cc)} = \text{Basis weight (gsm)} / [10,000 \text{ cm}^2 / \text{m}^2 \times \text{Thickness (cm)}]$$

As used herein, the term "unitary absorbent structure" or "absorbent structure" mean a structure or core of the invention containing one or more strata. When the unitary absorbent core contains a plurality of strata there is no interface between the strata, i.e. once the strata are disposed on each other they cannot be separated. Unitary absorbent structures which are formed from more than one strata are formed without glue or other adhesive between the layers. A unitary structure may be formed, for example, in a single manufacturing line, for example in a single airlaid line. Typically, airlaid absorbent cores contain a combination of cellulosic fibers, mixed with various functional synthetic fibers, functional particles or granulates and additives.

## **Absorbent Structures**

The present invention includes an absorbent structure which may be used as a core, having a profile of basis weight, density or SAP content in its y-direction, the direction

perpendicular to the longitudinal axis of a finished product. In particular embodiments, the structure may be profiled in both the y- and z- directions.

Prior art absorbent cores typically comprise strata that run the full width of the core. As shown in Figure 2a, in the existing art, all of the strata are of the same width. The present invention can be used to improve on the existing art by providing a method for selectively placing absorbent material where it can be used most efficiently. For example, as shown in Figure 2b, the present invention contemplates placement of absorbent material in a selective manner in the center of the unitary absorbent core, at the point of fluid insult, instead of uniformly distributing the absorbent material across the full width of the pad.

While 2b illustrates the use of strata having differing widths, in fact the structure of the invention will appear as Figure 2c, in which the strata having greater width will meet at the area where the stratum having lesser width is absent. The resulting structure is profiled in the y- and z-directions to form a zone containing greater basis weight, density or functional particle content.

Analogous to placing absorbent material in a unitary absorbent core where it can be used most efficiently, the present invention contemplates removal of material from the unitary absorbent core where it is not being used efficiently. Stratum profiling can be used to reduce raw-material costs by removing absorbent material from the unitary absorbent core where it is not effective.

With reference to Figure 3, wherein the y-direction and z-direction are indicated by arrows, the structure of the invention comprises at least one zone A, having one or more of higher basis weight, density or functional particle (such as SAP) content, and preferably at least two such zones A having one or more of higher basis weight, density or

functional particle (such as SAP) content, as well as at least one zone B having lower basis weight, density or functional particle content, or no functional particles. In one of the preferred embodiments the zones A have higher basis weight than the zones B. One, and more preferably two of the zones A, may be located at the edges on the sides of the absorbent structure.

For example, a y-directional and/or z-directional profile may be achieved by placing higher amount of SAP particles along with natural or synthetic fibers in narrow lanes creating zones A along the absorbent structure. Such zones are then separated by lower density lanes of natural or synthetic fibers with lower amount of SAP or no SAP, thus creating zones B. Such a controlled placement of SAP particles allows for better containment of the particles within the absorbent structure and allows for easier flow and wicking of the fluid along the length of the core (x-direction). The pliability of such a material can thus also be improved, particularly across the width of the core.

Further, the structures of the invention may have unexpectedly high fluid acquisition rate even at high SAP content, that is at SAP content higher than 30 percent. The absorbent structures known so far could not achieve such high acquisition rates at high SAP content because of the drastic loss in the permeability of these structures when they become saturated. This effect is associated with so called gel blocking of the SAP as the SAP particles swell and close the pores in the absorbent core. Without being bound to theory, it is believed that high acquisition rates of the structures of the invention, containing high amount of SAP, are due to the ability of these structures to maintain their high void volume and acquire more liquid in zones B (having one or more of lower basis weight, density or SAP content) even at high degree of saturation of the absorbent structure. It is also believed that the high void

volume in zones B can be maintained because the liquid is withdrawn from them by capillary forces to denser zones A, where it is retained by SAP particles in higher concentration. As a consequence of this, the structures of the invention have at the same time exceptionally high fluid acquisition and storage efficiency. This in turn allows for improved performance of the finished absorbent product, for example, a personal hygiene product, by reducing leakage during its use and for better utilization of the absorbent core. Increased amount of SAP in the absorbent core also enable manufacturers to produce thinner, more absorbent, and more comfortable absorbent articles.

One measurement used to evaluate the absorbent properties of a structure is fluid acquisition and storage efficiency ("FASE"). FASE is a dimensionless number, which is obtained by multiplying the fluid acquisition rate and the content of SAP particles in an absorbent structure. The higher the fluid acquisition rate and the higher the SAP particle content are, the higher is the FASE. However, so far, it has been difficult to achieve both high acquisition rate and high SAP particle content at the same time because any increase in the SAP particle content led in general to more gel blocking, less permeability and, consequently, to lower fluid acquisition rate. Desirably, the absorbent structures of this invention have a FASE of 50 or higher, more desirably 80 or higher, preferably 100 or higher and more preferably 180 or higher.

Referring to Figure 3, the fluid acquisition rate can be enhanced even further if the structure of the invention comprises a porous upper stratum C having essentially no x,y-wicking properties and capable of maintaining substantial dryness of the surface. Such a stratum may be made for example with a matrix of synthetic fibers bonded with a binder.

In some embodiments of the invention, stratum C is a low density acquisition stratum including from between 50 to 99 percent by weight of wettable synthetic fibers, preferably from 75 to 90 percent synthetic fibers, the balance of the stratum being binder material. Due to its relatively low density, large pore size, and lower wettability than that of the other strata below, the stratum C has essentially no x,y-aqueous liquid wicking capability. Fluid is easily wicked from it downward to the more wettable and smaller-pore, higher density strata below. In the preferred case, the stratum C would include synthetic fibers having a thickness of from 2 to 35 dtex, preferably of from 6 to 17 dtex. In this embodiment the synthetic fibers have a length of from 2 to 15 mm, preferably of from 4 to 12 mm. Optionally, the fibers may be crimped and may have a variety of cross-sectional shapes. Examples of suitable synthetic matrix fibers include polyethylene, polypropylene, polyester, including polyester terephthalate (PET), polyamide, polyacetates, cellulose acetate and rayon fibers. Certain hydrophobic synthetic fiber, such as polyolefins, should be surface treated with surfactant to improve wettability.

Preferred embodiments of the unitary absorbent structures of the invention contain at least one striped stratum. A striped stratum is a stratum in which one or more of the basis weight, density or functional particle (such as SAP) content drops to very low levels or zero for a finite length in the y-direction. This finite length of very low levels or zero basis weight, density or functional particle content can be continuous or can be parceled in discontinuous segments. The parceled segments can be distributed in a uniform pattern in the y-direction or there can be no uniform pattern. The finite length of very low levels or zero basis weight can be distributed symmetrically about the



longitudinal axis of the structure, or can be distributed asymmetrically about the longitudinal axis of the structure.

Figures 4a-4i depict representative, three-strata absorbent structure designs containing at least one striped stratum. Figures 4c, 4e, 4f and 4g depict absorbent structures with more than one striped stratum. As shown by Figure 4g, the striped strata do not necessarily have the same width. As shown by Figure 4, the invention contemplates absorbent structures with more than one stripe per stratum. As shown by Figure 4i, the invention also contemplates striped strata that are not centered with respect to the longitudinal axis of the structure. Figures 4a-i depict the absorbent structures in a theoretical manner. In fact, as explained in the discussion of Figures 2b and 2c, the strata having greater width will meet in the area where the stratum or strata having lesser width is absent.

Figures 5a-5d depict still additional embodiments of the absorbent structures of the present invention. Figures 5a-5d demonstrate how structures may be constructed stratum-by-stratum. In fact, in the structures of Figures 5a-5d the strata having greater width will meet in the area where the stratum or strata having lesser width is absent.

These additional embodiments can be produced by vacuum segmentation, i.e. by segmenting the vacuum system under the forming wire of the airlaid process. The vacuum system can be segmented into regions of relatively high vacuum and regions of relatively low vacuum. According to one method of the invention, the vacuum may be physically blocked in certain zones, in order to achieve zones of one or more of higher basis weight, density or functional particle (such as SAP) content. In alternative methods

of the invention, a block or mask may be used to shield the vacuum in desired zones, in order to achieve zones of one or more of higher basis weight, density or functional particle (such as SAP) content.

In an additional method of the invention, the distribution of air- bonded  
5 absorbent material is physically blocked in certain areas, so as to prevent deposition on the forming wire. Thus, a flow divider or other block may be disposed between the outlet of the forming head or particle applicator and the forming wire, to block the deposition of particles or fibers. This results in an absorbent structure which is profiled in the y-direction.

10 Figure 5a is an example of an absorbent structure having more than one strata, in which the bottom stratum is formed by blocking the deposition of particles or fibers at the edges of the forming wire, or by segmenting the vacuum system into a region of relatively high vacuum at the center of the forming wire and regions of relatively low vacuum at the edges of the forming wire. Thus, regions of high basis weight are formed  
15 by relatively high vacuum and regions of low basis weight are formed by relatively low vacuum or by blocking the deposition of fibers of particles. Figure 5b depicts an embodiment of the invention containing multiple regions of relatively high and relatively low basis weight in the y-direction. Figure 5c depicts an embodiment of the invention in which the center of mass of the unitary absorbent structure need not correspond to the  
20 longitudinal axis.

Figures 4 and 5 show examples of how the unitary absorbent structures of the present invention may be constructed, stratum by stratum on a typical airlaid line modified as described by the present invention. Once the strata have been formed, the

present invention provides for uniformly compacting or densifying the absorbent material. The compaction may also provide for unitary absorbent structures to be used as cores, having density variation in the CD.

The absorbent structure may also be used as cores in absorbent articles.

5 In one embodiment of an absorbent article of the invention, depicted in Figure 6, the structure of the invention comprises two separate absorbent structures (or plies), wherein the structures are in fluid communication with each other. The structure includes a shorter, upper structure 3, and a longer, lower absorbent structure 4. In general, the surface area of the bottom surface of upper structure 3 is less than 80 percent of the  
10 surface area of the upper surface of lower structure 4. This arrangement has an advantage over single-stratum structures by allowing for better containment and usage of the absorbent material during use of the absorbent article by the user. In Figure 6, the upper structure of this embodiment is a y-profiled absorbent structure comprising zones A and B (wherein zones A have one or more of higher basis weight, density or functional particle )  
15 content than zones B), of the type exemplified in Figure 3.

In another embodiment of an absorbent article, depicted in Figure 7, the lower structure 5 of the two-structure system is a profiled absorbent structure of the invention comprising zones A and B. The surface area of the bottom surface of upper structure 6 is less than 80 percent of the surface area of the upper surface of lower  
20 structure 5. Yet another example of the two-strata embodiment is a system, in which both the upper stratum and the bottom stratum are y-profiled structures of the invention comprising zones A and B.

Referring to Figure 6, the advantage obtained by providing a two structure system as described above, is that the fluid discharge from the human body occurs mainly over the frontal region 7 and central region 8 of the absorbent core. This embodiment places more of the absorbent capacity in the region where the liquid discharge insults the core.

### **Fibers**

The structures of this invention can include natural fibers, synthetic fibers or mixtures of both natural and synthetic fibers. Examples of the types of natural fibers which can be used in the present invention include fluffed cellulose fibers prepared from cotton, softwood and/or hardwood pulps, straw, keaf fibers, cellulose fibers modified by chemical, mechanical and/or thermal treatments, keratin fibers such as fibers obtained from feathers, bagasse, hemp, and flax, as well as man-made staple fibers made with natural polymers such as cellulose, chitin, and keratin. Cellulosic fibers include chemically modified cellulose such as chemically stiffened cellulosic fibers by crosslinking agents, fibers treated with mercerizing agents and cellulose acetate. Examples of suitable synthetic matrix fibers include polyethylene, polypropylene, polyester, including polyester terephthalate (PET), polyamide, polyacetates, cellulose acetate and rayon fibers. Certain hydrophobic synthetic fibers, such as polyolefins, should be surface treated with surfactant to improve wettability.

The final purity of the preferred cellulose fiber of the present invention may range from at least 80 percent alpha to 98 percent alpha cellulose, although purity of greater than 95 percent alpha is preferred, and purity of 96.5 percent alpha cellulose, is

most preferred. As used herein, the term "purity" is measured by the percentage of alpha cellulose present. This is a conventional measurement in the dissolving pulp industry. Methods for the production of cellulose fiber of various purities typically used in the pulp and paper industry are known in the art.

5 Preferred fibers used in zones having higher levels of basis weight, density or functional particle content (such as Zones B in Figure 3) are those which have lower water retention value (WRV). Water retention value (WRV) of cellulosic fibers is an indication of a fiber's ability to retain water under a given amount of pressure. Cellulose fibers that are soaked in water swell moderately, and physically retain water in the swollen  
10 fiber walls. When an aqueous fiber slurry is centrifuged, the majority of the water is removed from the fibers. However, a quantity of water is retained by the fiber even after centrifugation, and this quantity of water is expressed as a percentage based on the dry weight of the fiber.

The fibers having lower WRV value are in general stiffer than  
15 conventional fluff fibers and thus contribute to improved structure permeability. The preferred water retention value (WRV) of the cellulose fibers of the present invention is less than 85 percent, more preferably between 30 percent and 80 percent, most preferably 40 percent. The WRV refers to the amount of water calculated on a dry fiber basis, that remains absorbed by a sample of fibers that has been soaked and then centrifuged to  
20 remove interfiber water. The amount of water a fiber can absorb is dependent upon its ability to swell on saturation. A lower number indicates internal cross-linking has taken place. U.S. Patent No. 5,190,563 describes a method for measuring WRV.

Preferred fibers used in zones having lower levels of basis weight, density or functional particle content (such as Zones B in Figure 3) are those which have higher curl. Curl is defined as a fractional shortening of the fiber due to kinks, twists and/or blends in the fiber. The per cent curl of the cellulose fibers of the present invention is preferably from 25 percent to 80 percent, and is more preferably from 40 percent to 75 percent. For the purposed of this disclosure, fiber curl may be measured in terms of a two dimensional field.

Curl is defined as a fractional shortening of the fiber due to kinks, twists and/or bends in the fiber. The percent curl of the cellulose fibers of the present invention is preferably from 25 percent to 80 percent, and is more preferably 75 percent. For the purpose of this disclosure, fiber curl may be measured in terms of a two dimensional field. The fiber curl is determined by viewing the fiber in a two dimensional plane, measuring the projected length of the fiber as the longest dimension of a rectangle encompassing the fiber, L (rectangle), and the actual length of the fiber L (actual), and then calculating the fiber curl factor from the following equation:

$$\text{Curl Factor} = L(\text{actual}) / L(\text{rectangle}) - 1$$

A fiber curl index image analysis method is used to make this measurement and is described in U.S. Patent No. 5,190,563. Fiber curl may be imparted by mercerization. Methods for the mercerization of cellulose typically used in the pulp and paper industry are known in the art.

Another source of cellulosic fibers for use in the present invention, especially for use in zones having lower basis weight, density or functional particle content (zones B), is chemically stiffened cellulose fibers. As used herein, the term "chemically stiffened

cellulose fibers” means cellulose fibers that have been treated to increase the stiffness of the fibers under both dry and wet aqueous conditions. In the most preferred stiffened fibers, chemical processing includes intrafiber crosslinking with crosslinking agents while such fibers are in a relatively dehydrated, defibrated (i.e., individualized), twisted, curled condition.

5 These fibers are reported to have curl values greater than 70 percent and WRV values less than 60 percent. Fibers stiffened by crosslink bonds in individualized form are disclosed, for example, in U.S. Patent No. 5,217,445 issued June 8, 1993, and U.S. Pat. No. 3,224,946 issued Dec. 21, 1965.

Another source of cellulosic fibers for use in the present invention, especially  
10 for use in zones having lower basis weight, density or functional particle content, are fibers obtained from high-yield pulp, that is cellulose pulp containing lignin. Typical examples of such fibers are chemical thermo-mechanical pulp (CTMP) or bleached chemical thermo-mechanical pulp (BCTM). These fibers are stiffer both in dry and wet state than cellulose fibers with low or no lignin content.

#### 15 **Functional Particles**

Functional particles for use in the absorbent cores of the invention include particles, flakes, powders, granules or the like which serve as absorbents, odor control agents, e.g. zeolites or calcium carbonates, fragrances, detergents, antimicrobial agents and the like. The particles may include any functional powder or other particle having a  
20 particle diameter up to 3,000 $\mu$  (microns). In preferred embodiments, the particles are super absorbent polymer particles (“SAP”).

U.S. Patent Nos. 5,147,343; 5,378,528; 5,795,439; 5,807,916; and 5,849,211, which describe various superabsorbent polymers and methods of manufacture,

are hereby incorporated by reference. Examples of the types of SAP particles which may be used in this invention, include superabsorbent polymers in their particulate form such as irregular granules, spherical particles, staple fibers and other elongated particles. The term "superabsorbent polymer" or "SAP" refers to a normally water-soluble polymer, which has

5 been cross-linked. There are known methods of making water-soluble polymers such as carboxylic polyelectrolytes to create hydrogel-forming materials, now commonly referred to as superabsorbents or SAPs, and it is well known to use such materials to enhance the absorbency of disposable absorbent articles. There are also known methods of crosslinking carboxylated polyelectrolytes to obtain superabsorbent polymers. SAP

10 particles useful in the practice of this invention are commercially available from a number of manufacturers, including Dow Chemical (Midland, Michigan), Stockhausen (Greensboro, North Carolina), and Chemdal (Arlington Heights, Illinois). One conventional granular superabsorbent polymer is based on poly(acrylic acid) which has been crosslinked during polymerization with any of a number of multi-functional co-

15 monomer crosslinking agents, as is well known in the art. Examples of multifunctional crosslinking agents are set forth in U.S. Patent Nos. 2,929,154; 3,224,986; 3,332,909; and 4,076,673. Other water-soluble polyelectrolyte polymers are known to be useful for the preparation of superabsorbents by crosslinking, these polymers include carboxymethyl starch, carboxymethyl cellulose, chitosan salts, gelatin salts, etc. They are not, however,

20 commonly used on a commercial scale to enhance absorbency of disposable absorbent articles, primarily due to lower absorbent efficiency or higher cost.



Superabsorbent polymers are well-known and are commercially available. Superabsorbent particulate polymers are also described in detail in U.S. Patents 4,102,340 and Re 32, 649.

Suitable SAPs yield high gel volumes or high gel strength as measured by the shear modulus of the hydrogel. Such preferred SAPs contain relatively low levels of polymeric materials that can be extracted by contact with synthetic urine (so-called "extractables"). SAPs are well known and are commercially available from several sources. One example is a starch graft polyacrylate hydrogel marketed under the name IM1000 (Hoechst-Celanese; Portsmouth, VA). Other commercially available superabsorbers are marketed under the trademark SANWET (Sanyo Kasei Kogyo; Kabushiki, Japan), SUMIKA GEL (Sumitomo Kagaku Kabushiki; Haishi, Japan), FAVOR (Stockhausen; Garyville, LA) and the ASAP series (Chemdal; Aberdeen, MS). Most preferred for use with the present invention are polyacrylate-based SAPs. As used in the present invention, SAP particles of any size or shape suitable for use in an absorbent core may be employed.

### **Binders**

If the use of binders is preferred, examples of binders useful in the absorbent structure of the present invention include polymeric binders in a solid or liquid form. The term "polymeric binder" refers to any compound capable of creating interfiber bonds between matrix fibers to increase the integrity of the stratum. At the same time, the binder may optionally bind fibers and SAP particles to each other.

For example, a dispersion of natural or synthetic elastomeric latex may be used as a binder. Thermoplastic fibers or powder, which are well known in the art, are

also commonly used to provide bonding upon heating of the absorbent structure to the melting point of the thermoplastic fiber or powder. Other binders, which can be used for stabilizing the absorbent structure of the present invention, include bonding agents used to bond cellulose fibers. These agents include polymers dispersed in water, which are cured  
5 after application to the fibrous web and create bonds between fibers or between fibers and SAP particles. Examples of such agents include various cationic starch derivatives and synthetic cationic polymers containing crosslinkable functional groups such as polyamide-polyamine epichlorohydrin adducts, cationic starch, dialdehyde starch and the like. Any combination of the above-described polymeric binders may be used for stabilizing the  
10 structure of the present invention.

Suitable binders for use in the structures of the invention include binders in liquid form or having a liquid carrier, including latex binders. Useful latex binders include vinyl acetate and acrylic ester copolymers, ethylene vinyl acetate copolymers, styrene butadiene carboxylate copolymers, and polyacrylonitriles, and sold, for example, under the  
15 trade names of Airbond, Airflex and Vinac of Air Products, Inc., Hycar and Geon of Goodrich Chemical Co., and Fulatex of H. B. Fuller Company. Alternatively, the binder may be a non-latex binder, such as binding agents applied in aqueous solutions (for example kymene, dialdehyde starch, chitosan or PVA), or epichlorohydrin and the like.

For bonding the fibers specifically, and for structural integrity of the unitary  
20 absorbent structure generally, water-based latex binders may be used. Alternatively, or in combination with a latex binder, thermoplastic binding material (fibers or powders) may be used for bonding upon heating to the melting point of the thermoplastic binding material. Suitable thermoplastic binding material includes thermoplastic fibers, such as bicomponent

thermoplastic fibers ("bico"). Preferred thermoplastic binding fibers provide enhanced adhesion for a wide range of materials, including synthetic and natural fibers, particles, and synthetic and natural carrier sheets. An exemplary thermoplastic bico fiber is Celbond Type 255 Bico fiber from Hoechst Celanese.

5                   Other suitable thermoplastic fibers include polypropylenes, polyesters, nylons and other olefins, or modifications thereof. A preferred thermoplastic fiber is FiberVisions type AL-Adhesion-C Bicomponent Fiber, which contains a polypropylene core and an activated copolyolefin sheath.

10                   In certain embodiments, the binder in the invention is a binding fiber, which comprises less than about 10 percent by weight of the SAP particles. In other embodiments of the invention, the binder fibers comprise less than about 7 percent by weight of the absorbent structure.

**Airlaid Manufacture of a Structure of the Invention**

An absorbent structure having improved particle containment may be delivered in roll-goods form, or in other packaging formats such as festooning, and is particularly useful as an absorbent core for disposable absorbent articles such as diapers, adult incontinence pads and briefs, and feminine sanitary napkins.

Preferably, the structure of the present invention is prepared as an airlaid web. The airlaid web is typically prepared by disintegrating or defiberizing a cellulose pulp sheet or sheets, typically by hammermill, to provide individualized fibers. The individualized fibers are optionally mixed with functional particles, and are then air conveyed to one or more forming heads on the airlaid web forming machine. The forming head then deposits a stratum in the forming wire. A stratum may contain, for example, cellulose fibers, SAP and other functional particles, and bicomponent fibers.

In some embodiments, the structures of the invention contain a carrier tissue. The use of a compaction roll prior to the introduction of the particle areas eliminates the need for the tissue.

Through the use of flow dividers or vacuum blocks, each of the forming heads are adapted to provide a stratum having zones of one or more of higher basis weight, density or functional particle, e.g., SAP, content. Unit operations involve the use of multiple forming heads, for example, up to four, five, six or seven forming heads may be used to provide additional strata to the web. Any one or more than one of the strata may comprise zones of one or more of higher basis weight, density or functional particle, e.g., SAP, content.

According to the method of the invention, the zones may be obtained by physical blocking with a mask, preventing absorbent material from being deposited in specific zones, thereby resulting in an absorbent product with profiled strata. Alternatively, the zones may be obtained by vacuum segmentation, controlling the vacuum properties, after deposit  
5 of the stratum from the forming head. Vacuum segmentation may be used to control the width of the stratum. For example, the vacuum segmentation may be achieved by the use of a forming screen.

Several manufacturers make airlaid web forming machines, including M&J Fibretech of Denmark and Dan-Web, also of Denmark. The forming heads include rotating  
10 drums, or agitators generally in a racetrack configuration, which serve to maintain fiber separation until the fibers are pulled by vacuum onto a foraminous condensing drum or foraminous forming conveyor, or forming wire. For example, in machines manufactured by M&J Fibretech, the forming head includes a rotary agitator above a screen. Other fibers, such as a synthetic thermoplastic fiber, may also be introduced to the forming head through a fiber  
15 dosing system, which includes a fiber opener, a dosing unit and an air conveyor.

The airlaid web is transferred from the forming wire to a calender or other densification stage to densify the web, increase its strength and control web thickness. The fibers of the web may alternatively, or additionally, be bonded by application of a binder or foam addition system, followed by drying or curing. As a result, heat seals between the  
20 thermoplastic material and the fibers of the various strata are formed. The finished web is then rolled for future use.

Figure 8 depicts a process of making a fibrous web according to the present invention. Optionally, a carrier tissue 20 may be unwound from the supply roll 21. The tissue

20 is rolled on to forming wire 18. The tissue may alternatively be used as a carrier or as the lower stratum of the absorbent structure. As contemplated for the present invention, a forming head 24 of the airlaid web-forming machine distributes the desired fiber to form the lower stratum 23 of the absorbent structure. The strata may comprise further fibers, such as  
5 cellulosic fiber, thermoplastic fibers, and functional particles.

As contemplated by the present invention, one or more forming heads of the airlaid web forming machine distributes the desired fiber for the various strata of the absorbent core or structure. For example, a first forming head may be used to provide a first fibrous stratum, for example a stratum comprising a cellulose fiber, bicomponent fiber, and  
10 optionally a carrier tissue. The first stratum may be a wicking stratum.

Functional particles may optionally (or additionally) be applied to the lower strata by particle applicator 28. Thus, SAP particles or other functional particles are thus applied to stratum 23 deposited by forming head 24.

The deposition of fibers and particles in each strata is controlled in order to  
15 create zones of one or more of higher basis weight, density or functional particle content. As further described in Figure 9, forming wire 40 has flow dividers above or blocks 41, which are disposed over the forming wire, and below the outlet of the forming head. For example, the flow dividers 41 may be attached to a carriage or other device which is located above the forming wire. Fibers or particles which are deposited from the forming head are blocked from  
20 the forming wire. As a result, the stratum contains zones of one or more of higher basis weight, density or functional particle content. The zones can be varied by manipulation of the location or size of the flow dividers, or by variation of the types and amounts of fibers and functional particles in each stratum.

Figure 10 depicts the flow dividers 41 located above forming wire 40, along the direction A → B of Figure 9. In preferred embodiments, the flow dividers are tapered so that fibers or particles do not accumulate on the top of the divider. Also depicted in Figure 10 are vacuum blocks 42, which may be located below the forming wire in order to block the vacuum.

Returning to Figure 8, optionally the strata is compacted or densified in a nip formed by a pair of calender rolls 26. The fibers may be compressed to the desired thickness and density. The lower stratum 23 may be compacted at this point in the manufacturing process to close the pores of the web if the particles are fine, and to prevent spillage on to the forming wire.

Additional strata 27 and 28 can then be formed on top of lower strata 23 in the same manner the first stratum is formed, by use of forming heads 30 and 31, optionally particle applicators 33 and 34, and optionally nips formed by calender rolls at 35 and 36.

The airlaid web is transferred from the forming wire 18 and is compacted or densified, for example, by use of a calender 37 or to increase its strength and control web thickness. Preferred ranges of densification are from about 0.035 to about 0.50 g/cc, more preferably about 0.050 to about 0.50 g/cc, even more preferably about 0.20 g/cc. The web is then subjected to further treatment including pressure, heat and/or the application of a binder. For example, a binder (such as a spray or foam binder), may be applied at binder applicators, which may be disposed after the calendar 37. A series of ovens also may be used in processes of the invention, after application of the binder, for drying, curing or thermal bonding. The airlaid structure may be heated to a temperature in the range of from 125 to 180 °C. A further

overall binder may then be applied to the structure. This binder can be applied by spray, foam or mist, and is applied to reduce dust-off on the surface of the structure.

The air laid structure may be heated in additional ovens at a temperature in the range of from 125 to 180 ° C. The airlaid structure may be treated at pressure in the range  
5 of from 0.1 to 10 psi, preferably 1.5 psi.

The finished web is then rolled at roll 50 for future use. This continuous band of fibrous web can be slit or cut to form individual absorbent articles in a cutting unit, which has not been depicted in this figure.

Optionally, the finished web may be slit or perforated at the heat seal to yield  
10 narrow slit core material having a heat seal along both edges. The heat seals to be slit must be of sufficient width to provide two effective seals after slitting.

In other embodiments, various other strata containing other types and amounts of fibers may be applied above or below the upper and lower strata of the structure of the present invention. For example, the absorbent article may contain also a fluid previous top  
15 sheet and a fluid impervious backsheet. Exemplary absorbent articles which can be formed from absorbent cores of the invention include diapers, feminine sanitary napkins, and adult incontinence products.



**Test methods****1. Fluid Acquisition Time and Rate**

The Acquisition Time, the time for a given volume of saline solution to be absorbed by an absorbent structure (until any free liquid disappears from the surface of the absorbent) was measured.

The following method was used to measure the Acquisition Time:

1. Condition sample in lab at 21° C and 50 percent relative humidity for 2 hours prior to testing.

2. Prepare standard saline solution (0.9 percent NaCl in deionized water by weight). Add dye if desired.

3. Determine insult volume and load to be used. Medium capacity samples (most diapers of medium size (size #3)) use 3 x 75ml insults and 2.7 kPa load.

4. If sample is formed in lab or on pilot machine (airlaid), cut to 10 cm x 35.6 cm for samples made on the lab pad former, 10 cm x 40.6 cm for samples made on the pilot machine. If sample is a commercial diaper, simply cut elastic legbands so that diaper will lay flat. Take weight/thickness measurements of each sample.

5. Prepare airlaid samples by placing on plastic backsheet, Exxon EMB-685 polyethylene film, and adding coverstock material, 15 gsm Avgol spunbond polypropylene. Ensure that plastic backsheet material edges fold up toward top of sample to protect against leakage while testing.

6. Place sample in acquisition apparatus by placing sample on bottom plate, positioning foam piece on top of sample, placing insult ring into hole in foam, and then positioning weighted top plates over foam piece.

7. Set timer for 20 minutes and place beside test apparatus.

8. With stopwatch in one hand and graduate cylinder containing insult volume in other hand, prepare to insult sample. Pour fluid into insult ring. Start stopwatch at moment the fluid strikes the sample. Empty fluid from cylinder as quickly as possible. Stop stopwatch when fluid is absorbed by sample.

9. Note time taken by sample to absorb fluid. Start 20 minute timer as soon as fluid is absorbed by sample.

10. After 20 minutes, repeat steps 7-9.

11. After another 20 minutes, repeat steps 7-9. Note: If no other tests are to be done after the Acquisition test, the 20-minute interval following the third insult can be omitted. However, if another test is to be done following the Acquisition test (Rewet and Retention or Distribution), the 20-minute interval must be used and then the other test may be started.

The following formula is used to calculate the Acquisition Rate:

$$\text{Acquisition Rate (ml/s)} = \frac{\text{Insult Volume (ml)}}{\text{Acquisition Time (s)}}$$

## 2. Rewet Retention

The Rewet and Retention Test is designed to be performed immediately following the Acquisition Test. The Acquisition Test procedure must be followed before starting this test. If no acquisition information is needed, acquisition times do not have to be recorded, however the pattern of 3 insults separated by 20-minute intervals must be followed. It is imperative that the 20 minute interval has elapsed before starting this test. Sample/solution preparation is the same as in the Fluid Acquisition test.

1. Sample is now assumed to have been through the Acquisition Test and left undisturbed for the final 20-minute time interval. Set a timer for 5 minutes and place beside test apparatus.

2. Weigh stack of 10 Buckeye S-22 Blotter papers cut to same dimension as sample.

3. Remove weight over sample, foam piece, and insult ring.

4. Place stack of papers on sample.

5. Replace foam piece and weights over sample. Start 5-minute timer.

6. At end of 5 minutes, remove weight and weigh stack of papers.

Note weight differences between wet and dried papers. The rewet is calculated according to the formula:

$$\text{Rewet (g)} = \text{Weight of wet papers (g)} - \text{weight of dry papers (g)}$$

The following formula is used to calculate the Rewet Retention after the third insult:

$$\text{Rewet Retention (percent)} = \frac{\text{Vol. of All Insults (ml)} - (\text{Rewet (g)} \times 1 \text{ ml/g}) \times 100}{\text{Volume of ALL insults (ml)}}$$

### 3. Fluid Acquisition and Storage Efficiency

Fluid Acquisition and Storage Efficiency, FASE, is understood herein as a property of an absorbent structure combining its fluid acquisition performance with its fluid storage function, the latter being determined by the content of SAP particles. Fluid Acquisition and Storage Efficiency is defined here by the following formula:

$$\text{FASE} = (\text{Third Acquisition Rate, ml/s}) \times (\text{percent SAP}),$$

where Third Acquisition Rate is the rate of acquisition of the third insult measured according to the method described in the Section "Measurement of Fluid Acquisition Time and Rate", and percent SAP is weight per cent content of SAP particles in an absorbent structure or in an acquisition component of an absorbent structure. Fluid Acquisition Efficiency is presented as a dimensionless number although it is a product of multiplication of the acquisition rate expressed in milliliters per second and of the SAP content expressed in weight per cent. According to this definition, a structure exhibiting high fluid acquisition rate but containing no SAP particles will have Fluid Acquisition and Storage Efficiency equal to zero. The structures of this invention have FASE higher than 80, preferably higher than 120 and most preferably higher than 160.

#### 4. Absorbent Capacity

This method is used to test diapers and adult incontinence structures that typically consist of an absorbent core containing superabsorbent polymer (SAP). All samples should be conditioned at 70°F and 50 percent relative humidity prior to testing.

This test is used to evaluate an absorbent structure's ability to absorb and retain fluid after being submerged in a pool of saline solution. It is performed under load in order to simulate actual use of the product. From a performance standpoint, it is important that a structure be able to absorb as much fluid as possible. Even more importantly, the structure should be able to retain the fluid. Otherwise, the user will have a wet sensation and the product may leak. Absorbency and retention capacity are both reported in units of grams per gram.

The following procedure is used to measure Absorbent capacity:

## A. For commercial, finished product samples:

1. Remove leg cuffs, waistbands, etc. before cutting.
2. Measure the length of the core to be evaluated.
3. If the length of the core is  $\leq 35.6$  cm, e.g. all newborn diapers, use the 10 cm x 35.6 cm test apparatus.
4. If the length of the core is  $> 35.6$  cm, use the 10 cm x 40.6 cm test apparatus.
5. Most of the time, the core cannot be cut to measure exactly 35.6 cm or 40.6 cm in length. When this is the case, it is necessary to "make-up" for the smaller length to insure that the desired load is applied to the core. Therefore, cut a section out of another core in order to make the total sample length either 35.6 cm or 40.6 cm. (This piece should be 10 cm in width and taken from either the front or back section of the core.) Wrap this section of diaper in plastic in order to prevent any insult fluid from wicking or absorbing into it. Some adult incontinence products are larger than 40.6 cm. If this is the case, do not cut the product. Instead, fold to form a 10 cm x 40.6 cm sample.
6. Determine the weight and thickness of the sample only. (Record as "Dry Weight.") Before weighing the sample, remove the backsheet and coverstock. It is usually difficult to remove the coverstock without tearing it into pieces. However, it is important to remove the coverstock as best as possible. Instead of getting the coverstock's actual weight, assume it weighs 18 grams and subtract this amount from the sample weight.

B. For pad-former or machine-made (pilot or plant) samples:

1. Using a cutting board, cut samples to the required dimensions: 10 cm x 35.6 cm for samples made on the pad-former or 10 cm x 40.6 cm for samples made either on the pilot or plant lines.

- 5 2. Determine the weight and thickness of the sample. (Record as "Dry Weight.")

For all samples:

2. Condition the sample in the lab at 70°F and 50 percent relative humidity for 2 hours prior to testing. Samples that have already been tested do not need additional conditioning time since they were already tested in a conditioned lab space.
- 10 2. Prepare 0.9 percent saline solution. For better visibility, add food grade dye, if desired.
3. Determine what load (via weight plates) will be used for evaluation. Choose the load depending on the type of the finished product, for example for small-size diapers – 0.7 kPa (low capacity); medium size diapers – 2.7 kPa (medium capacity); Adult Incontinence, high capacity products – 2.7 kPa or 6.8 kPa (large capacity).
- 15 4. Place the sample on the screen of the Absorbency Tester (Figure 11A). Place the foam on top of the sample, followed by the required number of weight plates. For commercial cores, the coversheet should be in contact with the screen while the backsheet should be facing up. The same applies to pad-former and machine-made cores: the side of the sample that will be closest to the user should face the screen while the bottom of the core should face up.
- 20

5. Set the timer for 20 minutes.
6. Open the valve to allow fluid (0.9 percent NaCl solution, by weight, in deionized water) to flow from the zero head aspirator bottle. This will help to keep the fluid level constant.
- 5 7. Start the timer as soon as the sample is submerged into the saline solution container.
8. At least 2 minutes before the 20 minute time period expires, close the aspirator valve and open the air ejector aspirator pump valve in order to allow a vacuum to pull fluid from the base of the screen. In addition, turn on the water faucet in order to provide maximum vacuum. All of the liquid does not need to be removed;
- 10 however, there should be no fluid on the screen of apparatus B (Figure 11B).
9. When the appropriate time has elapsed, turn off the water faucet.
10. Remove the basket containing the sample and weight plates out of the container and drain on a flat plastic board that has been covered with blotter paper.
11. Drain for 5 minutes.
- 15 12. Remove the weight plates, foam, and weigh the wet sample. Record the weight as "Wet Weight Post Drainage."
13. Place a sheet of blotter paper on a flat surface. Place the sample on top of the blotter paper. Add the foam and weight plates.
14. Allow the sample to sit for 5 minutes.
- 20 15. Weigh the sample only. Record the weight as "Wet Weight Post Blotting."

The following formula is used to calculate Absorbent Capacity:

$$\text{Absorbent Capacity (g)} = \text{Wet Weight Post Blotting (g)} - \text{Dry Weight (g)}$$

The apparatus used to measure absorbency and retention is depicted in Figures 11A and 11B. The Absorbency Tester consists of two parts. Part A (Figure 11A) is a container to hold saline solution. A drain nozzle, which is located in the bottom of the container, should be about 2.5 cm long, and about 1 cm in diameter. A support cylinder with 1 cm gap is used to support drain nozzle. Part B (Figure 11B) has a fine screen (for example, 200 mesh screen bed). The screen is designed to hold a weight of up to 11.35 kg. The sample and weight plates are placed on top of this screen. Part B is placed inside of Part A.

The foam is used during the test for placing between the absorbent core and the weight plates. This foam is covered with plastic film (at least 4 mm thickness) and sealed in any appropriate way (heat seal, seal tape, etc.) such that a waterproof barrier is created around the foam.

##### 5. Wet Integrity

As used herein, "integrity" is a measure of the tensile strength of a fibrous sheet, normalized for unit basis weight and is expressed in units (milliNewtons, mN) of x-directional force required to break a 2.5 cm wide sample of the sheet per normalized basis weight of 1 gsm. In order to measure Wet Integrity (wet tensile strength) of an absorbent core or a commercial absorbent product, the following procedure is used:

1. 2.5 cm x 10 cm samples are prepared.
2. Remove any removable plastic backsheet, coverstock or synthetic acquisition material, leaving only the core.
3. Weigh sample. Apply 0.9 percent saline solution, in an amount equal



to twice the sample weight, to the center of the sample using pipette or spray bottle

(Example: sample weighs 1.00g. Apply 2.00g saline solution for total of 3.00g).

4. Insert sample into Tensile Tester (for example a Thwing-Albert LT-150 Universal Materials Tester, default software settings used for test) by placing in  
5 pressurized clamps.

5. Start test.

6. When test is finished, record results displayed. These results include Force at Peak, Elongation at Peak, Maximum Elongation, Energy at Peak, and Energy at Maximum.

10 The Wet Integrity as used herein is defined as the Force at Peak as measured by using the above procedure. The Wet Integrity of the absorbent structures of the present invention are higher than 4.0 mN/gsm, and preferably higher than 6.0 mN/gsm.

## 6. Softness

The softness of the absorbent structure is an important factor contributing  
15 to the overall conformability of the structure. As used herein, "softness" is the inverse of the amount of energy necessary to compress a sheet, in this case the sheet being the absorbent structure. The greater the amount of energy necessary to compress a sheet, the less soft it is.

To measure softness of the core, the following procedure (a modified  
20 compression test) is used:

1. Prepare samples by cutting three 10 cm x 20 cm pieces (if sample is a diaper, cut from the thicker section of diaper (if thickness is not uniform). For samples

with obvious machine direction and cross direction, cut 20 cm dimension in machine direction.

2. Allow plastic backsheet and coverstock material to remain on sample (applies to commercial diaper samples). If testing prototype core samples, apply plastic  
5 backsheet, Exxon EMB-685 polyethylene film, to bottom of sample and coverstock, 15 gsm Avgol spunbond polypropylene, to top of sample (same size as sample, adhered with a small amount of spray adhesive).

3. Program modified compression test (for example, a Thwing-Albert LT-150 Universal Materials Tester): Compression test using following non-default settings:  
10 Break Detection Method = % Drop/Displacement, Break Value = % Drop = 50, Distance Traps = 0.8cm/1.3cm/1.8 cm, Units: Distance/Displacement = cm; Force = grams, Test speed = 2.5 cm/min. All other settings left at defaults.

4. Insert sample into Tensile Tester using custom clamps as depicted in Figure 12. The clamp may be formed of .16 cm thick aluminum, and is 2.5 cm wide x 20  
15 cm long. The U-shape simulates the shape a diaper will take when placed on a baby. The function of the clamp is two fold. First, it facilitates the testing of a full width core. Second, it maintains the U-shape during the softness test, simulating the force required by the baby to compress the diaper between its legs, thus conforming to diaper of its body. The sample is inserted on its edge, such that it will be compressed in the y-direction (10  
20 cm direction), having 2.5 cm on both edges within the custom clamps, thus leaving a 5 cm gap.

5. Start test.

6. When deflection exceeds 1.8 cm, push down on top pressurized clamp to simulate a sample break and stop the test (does not affect test results). Record results displayed. These results include Force at Peak, Deflection at Peak, Maximum Deflection, Energy at Peak, and Energy at Maximum Deflection, and Force at Distance Traps.

5 The value, which is used to calculate the softness, is Energy at Maximum Deflection, which is expressed in Joules. Energy of Maximum Deflection,  $E_{d \max}$ , is calculated according to the following formula:

$$E_{d \max} = \int_{d \min}^{d \max} F \, dd$$

10

where  $E_{d \max}$  is Energy at Maximum Deflection,  $F$  is force at given deflection,  $d$ , and  $d \min$  and  $d \max$  are the deflections at the start of the test and at the end of the test, respectively.

Softness,  $S$ , is defined here according to the following formula:

$S = 1/(\text{Energy at Maximum Deflection})$ .

15 The result,  $S$ , is expressed here in 1 per Joule, 1/J.

In general, Softness of the overall absorbent structure of the present invention should be higher than 8.0/J, preferably higher than 15.0/J.

## 7. Pliability

The pliability of the absorbent structure is also an important factor contributing to the overall conformability of the sheet. As used herein, "pliability" is the inverse of the amount of force necessary to bend a sheet, in this case the sheet being the absorbent structure of the invention. The greater the force necessary to bend the sheet, the less pliable the sheet is.

Pliability can be measured by the following procedure, using a Gurley tester (Model 4171, Gurley Precision Instruments, Trey, NY). A sample Gurley Stiffness Tester is depicted at Figure 12.

1. Cut sample to 2.5 cm x 8.3 cm as accurately as possible. If there is a definite machine direction and cross direction, cut one sample in each direction and test each.

2. Fit custom clamp as shown in Fig. 12, over the original clamp provided with the Gurley tester, and tighten smaller, upper thumbscrews to secure (see Figure 12 illustrating the custom clamp for higher basis weight, lofty sheets). The custom clamp was designed in such a way that it does not change the thickness of the tested material, where the material is inserted into the clamp. If the thickness is changed as a result of clamping then the properties of the structure are changed and the results obtained by using the Gurley tester are affected. In the present method, the clamp of Figure 12 is used to eliminate such undesired effects.

3. The purpose of this custom clamp is to allow for the testing of samples that are too thick to be tested using the existing Gurley clamp without being compressed. The existing Gurley clamp allows for testing of samples having a maximum thickness of about 0.63 cm. Examples of structures tested using the custom clamp are commercial and prototype

diapers and diaper cores, and commercial and prototype adult incontinence structures. This custom clamp allows the sample to be tested without any z-directional structural compression, such as would be present if the existing clamp were used. This, therefore, removes the densification during testing issue, which can have a significant adverse effect on the test results.

4. Open the custom clamp adjustable plate by loosening longer, lower thumbscrews. Place sample in clamp by sliding sample up until it just contacts original clamp. There should be 5 cm of sample contained in the custom clamp.
5. Adjust height of custom clamp by loosening height adjustment screw on original clamp. Adjust height so that a gap of 2.5 cm exists between the point where the sample exits the custom clamp and the point where the sample will contact the lever arm.
6. Ensure that the remaining 0.6 cm of sample extends below the top of the lever arm. Ensure that lever arm is not moving. Press motor button to move sample towards lever arm. Continue pressing motor button until sample clears lever arm. While doing this, observe and note the highest number reached on the scale. Repeat this in the opposite direction.
7. Average the two values obtained. In the conversion chart on the apparatus, find the factor for a 2.5 cm wide x 3.8 cm long sample depending on the weight used and the distance the weight was placed from the center on the lever arm. A 2.5 cm x 8.3 cm sample tested using the custom clamp corresponds to a 2.5 cm x 8.3 cm sample tested without using the custom clamp. Without the custom clamp, 0.6 cm of sample is in the original clamp, 0.6 cm extends below the top of the lever arm, and 2.5 cm is the gap between. Using the custom clamp, the same 0.6 cm in the custom clamp is used; the other 4.4 cm in the custom clamp

secures the thicker sample in place. The same 0.6 cm extends below the top of the lever arm and the same 2.5 cm gap is in between.

8. Multiply the average reading on the scale by the appropriate conversion factor found on the chart.

5                   The result is Stiffness, which is expressed in milligrams force, mg. Pliability, P, is defined here according to the following formula:

$$P = 10^6/9.81 * \text{Stiffness.}$$

The result, P, is expressed here in 1 per Newton, 1/N. In general, Pliability of the entire absorbent structure of the present invention is higher than 60/N, preferably higher than 80/N.

10                   In the present invention, high levels of softness, pliability and wet integrity may be achieved by applying one or a combination of the following features in the preparation of an absorbent structure: by using soft fibers, curled or crimped fibers, by applying soft binder systems, such as for example fine or crimped binding fibers, elastic latex binders or water-soluble bonding agents, by minimizing the amounts of binder, applying relatively low  
15                   pressure during compaction before curing, and using relatively low pressure during the calendaring of the sheet after it has been cured. In general, the density of the sheet after compaction and/or calendaring in the absorbent structures of the invention should be lower than 0.35 g/cc, and preferably lower than 0.3 g/cc.

#### 8.     Thickness

20                   Thickness is measured using an analog thickness gauge (B.C. Ames Co.; Waltham, MA). The gauge has a 4.1-cm diameter foot and is equipped with a 150-gram

weight so that the pressure applied to the sample is 11.4 g/cm<sup>2</sup>. Thickness is measured in inches and is converted to centimeters as needed for calculations.

9. **Combination Acquisition and Rewet Test**

Equipment involved in this test includes the following materials:

5

Electronic balance ( $\pm 0.01$  g precision)

Fluid intake tester (FIT, Buckeye "B144-97" design)

Grade S22 blotter paper, 10.16 cm x 24.13 cm (4 in. x 9.5 in.)

Weight, 8408.5 g, 10.16 cm x 24.13 cm (4 in. x 9.5 in.)

Latex foam, 10.16 cm x 24.13 cm x 3.81 cm (4 in. x 9.5 in. x 1.5 in.)

10

Synthetic menstrual fluid

Topsheet, spunbond polypropylene, 22 gsm, 25.4 cm x 10.16 cm (10 in. x 4 in.)

15

Latex foam can be obtained from Scott Fabrics; Memphis, TN. Blotter paper can be obtained from Buckeye Technologies; Memphis, TN. The topsheet material can be obtained from Avgol Nonwoven Industries; Holon, Israel. The fluid intake tester (FIT), of Buckeye design, consists of a top plate and a bottom plate. The top plate is a 29.7 cm x 19.0 cm x 1.3 cm plate of polycarbonate plastic. The plate has a hole cut out of its center and a hollow intake cylinder is mounted in the hole. The inner diameter of the intake cylinder is 2.5 cm and the complete top plate weighs 872 grams. The bottom plate of the FIT is essentially a 29.7 cm x 19.0 cm x 1.3 cm monolithic plate of polycarbonate plastic.

20

The synthetic menstrual fluid used in the combination acquisition and rewet test contains the following ingredients in the designated amounts:

54

|   |                       |         |
|---|-----------------------|---------|
|   | Deionized water       | 903.3 g |
|   | Sodium chloride       | 9.0 g   |
|   | Polyvinylpyrrolidone  | 122.0 g |
|   | Biebrich Scarlet      | 4.0 g   |
| 5 | Total solution volume | 1 liter |

Biebrich Scarlet (red dye) can be obtained from Sigma Chemical Co.; St. Louis, MO. Polyvinylpyrrolidone (PVP, weight-average molecular weight approximately 55,000) can be obtained from Aldrich; Milwaukee, WI. Sodium chloride (ACS grade) can be obtained from J.T. Baker; Phillipsburg, NJ. The dry ingredients are mixed in water for at least two hours to ensure complete dissolution. The solution temperature is adjusted to 22°C exactly. 26 ml of solution is pipetted into the UL adapter chamber of a Brookfield Model DV-II+ viscometer (Brookfield Engineering Laboratories, Inc., Stoughton, MA). The UL spindle is placed into the chamber and the viscometer speed is set to 30 rpm. The target viscosity is between 9 and 10 centipoise. Viscosity can be adjusted with additional water or PVP.

15           The sample is cut to 7 cm x 20 cm with the longer dimension in the machine direction. The sample weight and thickness are measured and recorded. An "X" is placed at the center of the top of the sample with a marking pen. The sample is centered on the FIT bottom plate. The topsheet is centered on the sample and the FIT top plate is lowered on top of the topsheet. The top plate is centered on the sample so that the intake cylinder is centered on the "X" marked on the sample. A 10-ml insult of the synthetic menstrual fluid is poured into the intake cylinder and the amount of time taken for the sample to acquire the fluid is measured and recorded. This time, reported in seconds (s), is the acquisition time for the



sample. Simultaneous with the end of the acquisition time, a 20-minute waiting period begins. At the end of the waiting period, rewet is measured by removing the top FIT plate, then placing a pre-weighed stack of eight S22 blotter papers on the topsheet of the sample. The foam is placed on the paper and the weight is placed on top of the foam (the foam and the paper constitute a 3.4 kPa pressure on the sample) for two minutes. The rewet, reported in grams (g), is calculated by subtracting the initial weight of the stack of papers from the final weight of the stack of papers. This combination test is usually performed in triplicate and the results are averaged.

The structures of the present invention having y-directional profile in basis weight, density and SAP content may be employed in any disposable absorbent article intended to absorb and contain body exudates, and which are generally placed or retained in proximity with the body of the wearer. Disposable absorbent articles include infant diapers, adult incontinence products, training pants, sanitary napkins and other feminine hygiene products.

### **Exemplary Embodiments of the Invention**

The invention is illustrated here by performing a series of experiments in which unitary absorbent structures are produced and tested.

#### **Example 1 (Samples A through C)**

Samples A through C are three-strata, unitary absorbent cores that were manufactured on an airlaid pilot line containing three forming heads. For this group of samples, the second forming head of the pilot line was modified to form the striped strata of the present invention. In Samples A through C, the first or bottom wicking stratum comprised

70 gsm of Grade ND-416 pulp (Weyerhaeuser Co.; Tacoma WA), 7 gsm of bicomponent binder fiber (Grade AL-Adhesion-C, 1.7 dtex x 4 mm, FiberVisions; Covington, GA) and carrier tissue (absorbent core wrap, 18 gsm, Cellu Tissue Corporation; East Hartford, CT).

In Samples A through C, the third or top acquisition stratum comprised 35 gsm of polyester staple fiber (15 dpf x 6 mm, Grade 376X2, Wellman, Inc.; Johnsonville, SC) to which was applied an emulsion binder (6 gsm, Airflex 192, Air Products Polymers; Allentown, PA).

Sample A serves as the control for this group because it was not produced by practicing the present invention. In Sample A, the middle storage stratum comprised 50 gsm of Grade HPF pulp (Buckeye Technologies, Memphis, TN), 50 gsm of Favor SXM 70 superabsorbent powder (Stockhausen, Inc.; Greensboro, NC) and 7 gsm of Grade AL-Adhesion-C bicomponent binder fiber (1.7 dtex x 4 mm).

The present invention was used to construct the second or middle storage strata for Samples B and C. The objective was to keep the second strata weight the same as found in Sample A, but to increase the basis weight of the second stratum by concentrating absorbent material in a zone located in the center of Samples B and C. This was done by reducing the width of the second stratum and, concomitantly, fixing the total amount of absorbent material present in the stratum. Reducing the area over which the absorbent material was distributed increased the stratum basis weight. The standard product footprint for these examples was 70 mm by 200 mm. While keeping the overall weight of the stratum constant, the width of the middle stratum was reduced from 70 mm (full width, Sample A) to 55 mm (Sample B) to 40 mm (Sample C).

For Sample A (control), the target basis weight was 243 gsm and the target caliper was 2.85 mm, resulting in a target density of 0.085 g/cc. Samples B and C were also uniformly compacted to a target caliper of 2.85 mm.

Figure 14 is a schematic drawing indicating how samples A through C were formed, stratum by stratum. Figure 14 indicates that the basis weight and density of sample A should be constant across its width. However, Figure 14 also indicates that, compared to sample A, samples B and C should have regions of higher basis weight and density at their centers and regions of lower basis weight and density at their edges.

Figure 15 shows the y-direction basis weight profiles that were measure for samples A through C. The basis weight for sample A is uniform. The basis weight of the edges for samples B and C are the same, indicating the absence of a contribution to the overall basis weight from the second or middle storage stratum. As indicated by the schematic drawings of Figure 14, the basis weight is the center of the unitary absorbent cores increased from sample A to sample B to Sample C.

Samples A through C were compacted to the same thickness on the airlaid pilot line. Figure 16 shows y-direction density profiles for Samples A through C. Figure 14 shows the increase in density in the center as the basis weight increased in the center at fixed thickness. Figure 16 shows the decrease in density in the edges as the basis weight decreased in the edges at fixed thickness.

## **Example 2 (Samples D through G)**

Samples D to G show how the present invention can be used to improve product performance over the conventional technology.

Samples D and E are three-strata, unitary absorbent cores that were manufactured on an airlaid pilot line containing three forming heads. The first or bottom wicking stratum for these examples comprised 101.8 gsm of Grade ND-416 pulp (Weyerhaeuser Co; Tacoma WA), 8.9 gsm of bicomponent binder fiber (Grade AL-Adhesion-C, 1.7 dtex x 4 mm, FiberVisions; Covington, GA) and carrier tissue (absorbent core wrap, 18 gsm, Cellu Tissue Corporation; East Hartford, CT).

The second or middle storage stratum comprised 50 gsm of Grade HPF pulp (Buckeye Technologies; Memphis, TN), 50 gsm of Favor SXM 70 superabsorbent powder (Stockhausen, Inc.; Greensboro, NC) and 7 gsm of Grade AL-Adhesion-C bicomponent binder fiber (1.7 dtex x 4 mm). The third or top acquisition stratum comprised 35 gsm of polyester staple fiber (15 dpf x 6 mm, Grade 376X2, Wellman, Inc.; Johnsonville, SC) to which was applied an emulsion binder (6 gsm, Airflex 192, Air Products Polymers; Allentown, PA).

For Sample D, the first forming head of the pilot line was modified to form the striped strata of the present invention. The standard product footprint is 70 mm by 200 mm. For Sample D, the first strata was formed in two 22.3-mm stripes with a 25.4-mm gap between the stripes. Sample E was constructed in the conventional way to serve as a control. Note that the basis weight and density in the center of sample D was lower than the basis weight and density of sample E. Both samples were compacted to a thickness of 2.97 mm.

Figure 17A is a schematic drawing indicating how sample was formed, stratum-by-stratum, and Figure 17B is a schematic drawing indicating how Sample E was formed, stratum-by-stratum. In Figures 17A and 17B, the longitudinal axis of the product is normal to the plane of the drawing. Figures 17A and 17B do not indicate the end-view

profiles of the actual finished products after they were uniformly compacted to target thickness.

Table 1 shows acquisition and rewet data for samples D and E. Acquisition was faster and rewet was lower for sample D compared to control, sample E. It is well known to those skilled in the art that acquisition time can be a strong function of absorbent-core density. The lower density in the central portion of sample D accounts for its shorter acquisition time.

**Table 1. Acquisition and rewet data for Samples D and E**

| Sample | Configuration | Acquisition time(s) | Rwet (g) |
|--------|---------------|---------------------|----------|
| D      | Profiled      | 9.9                 | 1.32     |
| E      | Control       | 16.8                | 1.73     |

Samples F and G are two-strata, unitary absorbent cores that were manufactured using a laboratory pad former of Buckeye design (Buckeye Technologies; Memphis, TN). For these samples, the forming screen of the laboratory pad former was modified to form the striped strata of the present invention. These cores were formed upside down in the laboratory pad former (the top strata of the cores were formed first and the bottom strata of the cores were formed second).

Sample G serves as the control for this pair of samples. A top stratum was formed on topsheet material that also functioned as a carrier (polypropylene spunbond with durable hydrophilic finish, 22 gsm, Avgol Nonwoven Industries; Holon, Israel). This stratum comprised 92 gsm of fluff pulp (Foley Fluffs, Buckeye Technologies; Memphis, TN) and 10

gsm of bicomponent binder fiber (Grade AL-Adhesion-C, 1.7 dtex x 4 mm, FiberVisions; Covington, GA).

The present invention was used to construct the top stratum for sample F. The objective was to keep the top stratum weight the same as found in sample G, but to increase the basis weight of the top stratum by concentrating absorbent material in the center of F. This was done by reducing the width of the top stratum and, concomitantly, fixing the total amount of absorbent material present in the stratum. Reducing the area over which the absorbent material was distributed increased the stratum basis weight. The standard product footprint for these samples was 70 mm by 200 mm. While keeping the overall weight of the stratum constant, the width of the top stratum was reduced from 70 mm (full width, sample G) to 44 mm (sample F).

In samples F and G, the bottom stratum comprised 59 gsm of fluff pulp (Foley Fluffs, Buckeye Technologies; Memphis, TN), 7 gsm of bicomponent binder fiber (Grade AL-Adhesion-C, 1.7 dtex x 4 mm, FiberVisions; Covington, GA), 50 gsm of Favor SXM 70 superabsorbent powder (Stockhausen, Inc.; Greensboro, NC).

For sample G (control), the target basis weight was 240 gsm and the target caliper was 2.67 mm, resulting in a target density of 0.090 g/cc. Sample F was also uniformly compacted to a target caliper of 2.67 mm.

Figure 18 is a schematic drawing indicating how samples F and G were formed, stratum-by-stratum. Samples F and G were formed upside down in the laboratory former, but their profiles are depicted right side up in Figures 18A and 18B, respectively. In Figure 18, the longitudinal axis of the product is normal to the plane of the drawing.

Table 2 shows acquisition and rewet data for samples F and G. Product dryness, as measured by the rewet test, was better for sample F over the control (Sample G). Absorbent material was concentrated in the central portion of sample F, resulting in improved rewet over control.

5                    Acquisition was slower in sample F compared to control, sample G. It is well known to those skilled in the art that acquisition time can be a strong function of absorbent-core density. The higher density in the central portion of sample F accounts for the longer acquisition time.

**Table 2. Acquisition and rewet data for Samples F and G**

10

| Sample | Configuration | Acquisition time(s) | Rewet(g) |
|--------|---------------|---------------------|----------|
| F      | Profiled      | 51.28               | 4.42     |
| G      | Control       | 37.7                | 4.93     |

**Example 3 (Samples H and J):**

15                    The next several samples show how the present invention can be used to maintain performance while reducing raw material costs.

                    Samples H and J are three-strata, unitary absorbent cores that were manufactured on an airlaid pilot line containing three forming heads. The first or bottom wicking stratum for these samples comprised specified amounts of Grade ND-416 pulp (Weyerhaeuser Co.; Tacoma WA). The first stratum for samples H and J contained 60 gsm  
20                    of ND-416 pulp. See Table 4. The first stratum for these examples also contained 7 gsm of bicomponent binder fiber (Grade AL-Adhesion-C, 1.7 dtex x 4 mm, FiberVisions, Covington;

GA) and carrier tissue (absorbent core wrap, 18 gsm, Cellu Tissue Corporation; East Hartford, CT).

**Table 3. Product parameters and rewet data for Samples H through K**

| Sample | Bottom<br>stratum<br>width (mm) | Bottom stratum<br>basis<br>weight (gsm) | Rewet(g) |
|--------|---------------------------------|---|----------|
| H      | 55                              | 60                                      | 1.97     |
| J      | 40                              | 60                                      | 1.69     |

The second or middle storage stratum comprised 50 gsm of Grade HPF pulp (Buckeye Technologies; Memphis, TN), 50 gsm of Favor SXM 70 superabsorbent powder (Stockhausen, Inc.; Greensboro, NC) and 7 gsm of Grade AL-Adhesion-C bicomponent binder fiber (1.7 dtex x 4 mm).

The third or top acquisition stratum comprised 35 gsm of polyester staple fiber (15 dpf x 6 mm, Grade 376X2, Wellman, Inc.; Johnsonville, SC) to which was applied an emulsion binder (6 gsm, Airflex 192, Air Products Polymers; Allentown, PA).

For this group of samples, the first forming head of the pilot line was modified to form the striped strata of the present invention. The standard product footprint is 70 mm by 200 mm. For sample H, the first stratum was formed in one 55-mm wide stripe centered about the longitudinal axis of the product. For sample J, the first stratum was formed in one 40-mm wide stripe centered about the longitudinal axis of the product. Table 3 shows the basis weights and widths for the bottom strata for samples H and J.



Samples H and J were uniformly compacted to a target density of 0.085 g/cc.

The target basis weight in the central portions of samples H and J was 233 gsm.

Figure 19 shows rewet data for Samples H and J as a function of the basis weight and width of the bottom wicking stratum. Figure 19 shows that rewet is essentially flat with respect to stratum width. Assuming that the rewet performance shown here is acceptable, the examples with the narrower width would be favored based on raw material costs.

#### **Example 4**

Seven commercially available brand diaper products (products 1-7) were tested for SAP % content in the absorbent core, absorbency, rewet retention and third acquisition time. The results are summarized in Table 4.

**Table 4**

| Product | Overall Avg. Basis Wt (gsm) | Overall SAP Content (Wt Percent) | Absorbent Capacity (g) | Rewet (g) | Rewet Retention (Percent) | Third Acquisition Rate | FASE |
|---------|-----------------------------|----------------------------------|------------------------|-----------|---------------------------|------------------------|------|
| 1       | 710                         | 40.1                             | 443                    | 0.4       | 99.8                      | 0.55                   | 22.1 |
| 2       | 600                         | 30.5                             | 422                    | 5.3       | 97.7                      | 0.71                   | 21.7 |
| 3       | 658                         | 36.8                             | 321                    | 16.2      | 92.8                      | 1.24                   | 45.6 |
| 4       | 719                         | 39.9                             | 251                    | 3.4       | 98.5                      | 0.83                   | 33.1 |
| 5       | 680                         | 37.7                             | 551                    | 0.6       | 99.7                      | 0.25                   | 9.4  |
| 6       | 820                         | 42.6                             | 537                    | 0.7       | 99.7                      | 0.33                   | 14.1 |
| 7       | 750                         | 14.7                             | 422                    | 15.8      | 93.0                      | 0.21                   | 3.1  |

Comparison of the data in Table 4 with the data in Tables 5 and 6 reveals that the absorbent systems comprising y-directionally profiled absorbent structures have considerably higher FASE values than any of the tested commercial absorbent articles.

#### **Example 5**

5                   The absorbent samples tested in Example 4 were used for reference to compare the performance of systems without y-directionally profiled structures (Example 4) to the systems containing y-directionally profiled structures (Examples 5 and 6).

                  The following raw materials were used as structural components of the samples described in Example 5 and 6:

- 10       a) Foley Fluff (FF)- bleached southern softwood Kraft (BSSK) fibers from Buckeye Technologies; Memphis, Tennessee;
- b) ND 416 compressible pulp available from Weyerhaeuser Company; Tacoma, Washington;
- c) Chemically crosslinked fibers (CS) such as those described in U.S. Pat. No. 5,190,563 by treating Southern Softwood Kraft pulp with citric acid and sodium hypophosphite. The fibers
- 15       had WRV of about 40% and Curl Factor of about 0.5;
- d) Polyethylene terephthalate (PET) fibers having the name of Fillwell 093™, Wellman PET 376X2, having thickness of 16.7 dtex per fiber (dtexpf) and length of 6 mm, available from Wellman International Limited; Mullagh, Kells, County Meath, Ireland;
- e) Superabsorbent polymers:
- 20               -       FAVOR™ SXM 3950, obtained from Stockhausen GmbH & CoKG.; Krefeld Germany

- FAVOR™ SXM 9100 obtained from Stockhausen GmbH & CoKG.; Krefeld Germany
- K - SAM™ MG-2600 obtained from Kolon Chemical Co., LTD.; Kwacheon-City Kyunggi-Do, Korea;
- 5       - K - SAM™ MG-3500 obtained from Kolon Chemical Co., LTD.; Kwacheon-City Kyunggi-Do, Korea;
- f) Licontrol™ nonwoven acquisition stratum having basis weight of 48 gsm, reference number 381002-0000 from Jacob Holm Industries; Alsace, France SAS;
- g) AirFlex™ 124 latex emulsion available from Air Products Polymers, L. P.; Allentown, 10       Pennsylvania;
- h) T255™ bicomponent, crimped binder fiber having thickness of 2.3 dtexpf and length of 6mm available from Kosa; Houston, Texas;
- i) Fiber Vision bicomponent binder fiber having thickness of 1.7 dtexpf and length of 6 mm, available from FiberVisions; Varde, Denmark.

15               The absorbent samples used in Example 5 consisted each of an upper stratum and a lower stratum, both strata having rectangular shape. Each upper stratum was 10 cm wide and 20 cm long, whereas each lower stratum was 10 cm wide and 40.6 cm long. For testing the acquisition time and rewet of each absorbent sample, the upper stratum was placed on the top of the lower stratum so that the front edges of both plies were on the same line.

20       For the absorbent sample "L" and "M" the same lower ply material X612 was used. The sample "N" consisted of higher basis weight upper (DX119) and bottom (DX122) plies described in this Example.

The lower stratum material, X612, basis weight of 330 gsm, and used in Example 6, was produced on an M&J commercial air laid machine by forming an absorbent on Cellutissue 3024, an 18 gsm carrier tissue. The absorbent was formed in four steps. First a homogeneous stratum comprised of 37 gsm ND416 pulp fibers, 92.3 gsm of Favor™ SXM 3950, and 4.0 gsm T-255™ (2.3dtexpf) bicomponent staple fiber. A second homogeneous stratum comprised of 37 gsm ND416 pulp fibers, 92.3 gsm of Favor™ SXM 3950, and 4.0 gsm T-255 (2.3dtexpf) staple fiber. A third homogeneous stratum comprised of 38.5 gsm ND416 pulp fibers and 6.9 gsm T-255 (2.3dtexpf) staple fiber. Water in an amount of 49.1 gsm was sprayed on top of the third stratum before the drying and curing stage.

Sample L was made using an upper stratum material produced on a Danweb pilot air laid machine in the following manner: The nonwoven acquisition stratum type Licontrol™ 48 gsm was used as a forming sheet. The absorbent structure was formed on the spunbond side of the two-strata nonwoven. The raw materials were homogeneously mixed consisting of 144 gsm FF pulp fibers, 150 gsm Favor™ SXM 9100 and 6.0 gsm FiberVision (1.5 dpf). Total basis weight was 348 gsm.

Sample M was made using an upper stratum material produced on a Danweb pilot air laid machine. The nonwoven acquisition stratum type Licontrol™ 48 gsm was used as a forming sheet. The absorbent structure was formed on the spunbond side of the two-strata nonwoven. The raw materials, consisting of 144 gsm CS fibers, 150 gsm Favor™ SXM 9100 and 6.0 gsm FiberVision (1.7 dtexpf), were homogeneously mixed. Total basis weight was 348 gsm.

Sample N consisted of DX119 material as an upper ply and DX122 material as a lower ply.

DX119 material was made in the following manner:

A cellulose based tissue, Cellutissue 3024 18 gsm, was first applied and used as a transfer/carrier medium for the subsequent material. The next stratum consisted of a uniform blend of 130 gsm Southern Softwood pulp fibers (Foley Fluff), 103.5 gsm superabsorbent Kolon MG 2600, and 7.5 gsm self adhesion bicomponent fiber with a polypropylene core and polyethylene sheath (Fiber Visions 1.7 dtexpf/ 4mm cut). The next stratum consisted of a uniform blend of 130 gsm of Foley Fluff, 103.5 gsm of Kolon MG 2600, and 7.5 gsm of Fiber Vision bicomponent fiber, 1.7 dtexpf/ 4mm cut. The last or top stratum was 42 gsm poly (ethylene terephthalate) fibers Wellman™ PET 376 x 2, 16.7 dtexpf and 8 gsm binder Air Products AF 124 latex binder used at 10 percent solids. The web was densified to 0.07 g/cc before curing. The total basis weight of the material was 547 gsm.

DX122 material was made in the following manner:

A cellulose based tissue, Cellutissue 3024 18 gsm, was first applied and used as a transfer/carrier medium for the subsequent material. The next stratum consisted of a uniform blend of 117 gsm highly compressible softened pulp fibers (ND416), 85 gsm high permeable superabsorbent (Kolon MG 2600), and 11 gsm self adhesion bicomponent fiber with a polypropylene core and polyethylene sheath (Fiber Visions 1.7 dtexpf/ 4mm cut). The next stratum consisted of a uniform blend of 117 gsm of ND416, 201 gsm of Kolon MG 2600, and 4 gsm of Fiber Vision bicomponent fiber 1.7 dtexpf/ 4mm cut. The last or top stratum was 5 gsm binder add on of Air Products AF 124 latex binder at 14 percent solids. The web was densified to 0.15 g/cc before curing. The total basis weight of the material was 550 gsm.

**Table 5. Properties of Samples L to N**

| Sample | Overall Avg. Basis wt (gsm) | Overall SAP Content (%) | Absorbent Capacity (g) | Rewet (g) | Rewet Retention (%) | Third Acquisition Rate (mL/sec) | FASE |
|--------|-----------------------------|-------------------------|------------------------|-----------|---------------------|---------------------------------|------|
| L      | 504                         | 54.2                    | 373                    | 9.4       | 96.0                | 0.88                            | 47.7 |
| M      | 504                         | 54.2                    | 398                    | 6.5       | 97.1                | 1.50                            | 81.3 |
| N      | 824                         | 42.9                    | 550                    | 2.9       | 98.7                | 1.36                            | 58.3 |

The data in Tables 4, 5, 7 and 10 clearly demonstrate the superiority of absorbent systems comprising y-directionally profiled structures over the absorbent systems without such profiled structures.

#### **Example 6**

The absorbent samples tested in Example 6 consisted each of an upper stratum and a lower stratum, both strata having rectangular shape. Each upper stratum had a y-directional profile described in Table 5 and was 10 cm wide and 20 cm long whereas each lower ply was 10 cm wide and 40.6 cm long. For testing the acquisition time and rewet of each sample, the upper ply was placed on the top of the lower ply so that the front edges of both plies were on the same line.

The lower stratum material, named as X612, was the same as described in Example 5.

Sample O was made using an upper stratum material produced on a Danweb pilot air laid machine in the following manner: The Licontrol™ nonwoven acquisition stratum was used as a forming sheet. The first stratum was formed on the spunbond side of the two-strata nonwoven. The first stratum formed was the high-density zone A region as 5.1

cm, spaced 5.1 cm stripes running in the MD direction. The stripes were composed of 175 gsm ND416 pulp fibers, 281 gsm Favor™ SXM 9100, and 14.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously mixed. The second stratum filled zone B. It consisted of 62 gsm FF pulp fibers, 66 gsm Favor™ SXM 9100 and 4.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously mixed filling the areas between the high-density zone A region. Total basis weight was 348 gsm.

Sample P was made using an upper stratum material produced on a Danweb pilot air laid machine in the following manner: The Licontrol™ nonwoven acquisition stratum was used as a forming sheet. The first stratum was formed on the spunbond side of the two-strata nonwoven. The first stratum formed was the high-density zone A region as 5.1 cm, spaced 5.1 cm stripes running in the MD direction. The stripes were composed of 175 gsm ND416 pulp fibers, 281 gsm Favor™ SXM 9100, and 14.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously mixed. The second stratum filled zone B. It consisted of 62 gsm CS pulp fibers, 66 gsm Favor™ SXM 9100 and 4.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously mixed filling the areas between the high-density zone A region. Total basis weight was 348 gsm.

Sample Q was made using an upper stratum material produced on a Danweb pilot air laid machine in the following manner: The Licontrol™ nonwoven acquisition stratum was used as a forming sheet. The first stratum was formed on the spunbond side of the two-strata nonwoven. The first stratum formed was the high-density zone A region as 5.1 cm, spaced 5.1 cm stripes running in the MD direction. The stripes were composed of 175 gsm ND 416 pulp fibers, 281 gsm Favor™ SXM 9100, and 14.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously

mixed. The second stratum filled zone B. It consisted of 62 gsm Fillwell 093™ Wellman PET 376X2 16.7 dtexpf 6 mm synthetic staple fibers, 66 gsm Favor™ SXM 9100 and 4.0 gsm FiberVision (1.7 dtexpf) bico staple fibers. These materials were homogeneously mixed filling the areas between the high-density zone A region. Total basis weight was 348 gsm.

**Table 6**

| Y-Profiled Structure in Sample | Zone A         |                           |                       |                 | Zone B         |                           |                       |                 |
|--------------------------------|----------------|---------------------------|-----------------------|-----------------|----------------|---------------------------|-----------------------|-----------------|
|                                | Basis wt (gsm) | Density g/cm <sup>3</sup> | SAP Content (Percent) | Zone Width (cm) | Basis wt (gsm) | density g/cm <sup>3</sup> | SAP content (Percent) | Zone Width (cm) |
| O                              | 551            | 0.305                     | 60                    | 2.5             | 273            | 0.203                     | 50                    | 5.1             |
| P                              | 562            | 0.214                     | 60                    | 2.5             | 282            | 0.136                     | 50                    | 5.1             |
| Q                              | 749            | 0.277                     | 60                    | 2.5             | 303            | 0.140                     | 50                    | 5.1             |

Zones A and B, basis weights and densities for each zone were calculated values from total weight and bulk measurements.

**Table 7**

| Sample | Overall SAP Content (%) | Absorbent Capacity (g) | Rewet (g) | Rewet Retention (Percent) | Third Acquisition Rate (mL/sec) | FASE  |
|--------|-------------------------|------------------------|-----------|---------------------------|---------------------------------|-------|
| O      | 54.2                    | 390                    | 4.29      | 98.1                      | 1.94                            | 105.1 |
| P      | 54.2                    | 408                    | 1.35      | 99.4                      | 3.73                            | 202.2 |
| Q      | 54.2                    | 437                    | 2.49      | 98.9                      | 3.41                            | 184.8 |

Analysis of the data in Tables 4, 5, 6 and 7 reveals that the absorbent samples comprising y-directionally profiled absorbent structures have considerably higher



FASE values than any of the commercially available and tested absorbent articles, as well as absorbent samples without y-directional profile. The highest FASE values were obtained with the y-profiled structures, in which zones B comprised either crosslinked cellulose fibers (CS) or PET fibers (Wellman™ PET 376X2 16.7 dtexpf).

5                   The y-profiled upper ply components of the samples P and Q were tested for wet integrity, softness and pliability. The results are shown in Table 8.

**Table 8**

| Sample    | Wet integrity, mN/gsm, high density area | Wet integrity mN/gsm, low density area | Softness, I/J complete sample | Pliability, 1/N high density area | Pliability, 1/N low density area |
|-----------|--|--|-------------------------------|-----------------------------------|----------------------------------|
| P         | 39.2                                     | 93.1                                   | 73.9                          | 470                               | 278                              |
| 10      Q | 28.8                                     | 74.6                                   | 97.3                          | 371                               | 230                              |

**Example 7**

The absorbent samples tested in Example 7 consisted each of an upper stratum and a lower stratum, both plies having rectangular shape. The upper stratum was Unicore 8902 material which is commercially available from Buckeye Technologies Inc.

15   It was 9 cm wide and 20 cm long. The lower ply was 10 cm wide and 35.6 cm long. For testing the acquisition time and rewet of each absorbent system, the upper stratum was placed on the top of the lower stratum so that the front edges of both strata were on the same line.

Sample R contained a lower stratum made in a laboratory pad former in the following manner:

1. A carrier tissue (Cellutissue 3024, an 18gsm cellulosic tissue), was laid down.
2. The first set of material lanes were deposited. This was accomplished using a  
5 variant grid. The variant grid consisted of alternating 10mm open and 10mm  
blocked lanes. The first set of lanes deposited material consisted of Aracruz  
Eucalyptus fiber at a weight of 86gsm and FiberVisions 1.7dtexpf/4mm  
bicomponent fiber at a weight of 12gsm. These weights represent material weights  
in the first 10mm wide lanes only. The overall average gsm for the pad is therefore  
10 half of these in-lane-only gsm's.
3. The variant grid was then shifted 10mm in the cross direction such that the open  
areas of the grid were then over the empty lanes of the pad. The second set of  
material lanes were then deposited. The deposited material consisted of  
Weyerhaeuser ND416 fiber at a weight of 86gsm, FiberVisions 1.7dtexpf/4mm  
15 bicomponent fiber at a weight of 12gsm, and Stockhausen SXM70 superabsorbent  
polymer at a weight of 368gsm. These weights represent material weights in the  
second set of 10mm wide lanes only. The overall average gsm for the pad is  
therefore half of these in-lane-only gsm's.
4. The resulting structure was then densified using a laboratory roller press. Resultant  
20 density for the first set of material lanes was 0.06g/cc. Resultant density for the  
second set of material lanes was 0.28g/cc.
5. A latex spray was then applied to the structure above stratum 2. Latex used was  
Air Products Airflex 124. Latex spray was a 10 percent solids mixture. This

mixture also contained Aerosol OT (75 percent) surfactant added at a 0.1 percent level. The mixture sprayed resulted in a 2gsm latex solids add-on to the sample.

6. The sample was then dried/cured in an oven (Lindberg/Blue M) for 25 minutes at 150°C.

5 **Table 9**

| Y-profiled<br>structure in<br>sample | Zone A                       |                 | Zone B                       |                 |
|--------------------------------------|------------------------------|-----------------|------------------------------|-----------------|
|                                      | density (g/cm <sup>3</sup> ) | zone width (cm) | density (g/cm <sup>3</sup> ) | zone width (cm) |
| R                                    | 0.28                         | 1.0             | 0.06                         | 1.0             |

10 **Table 10**

| Sample | Overall<br>target SAP<br>content (%) | Absorbent<br>Capacity (g) | Rewet<br>Retention<br>(%) | Third<br>Acquisition<br>Time (sec) | FASE  |
|--------|--------------------------------------|---------------------------|---------------------------|------------------------------------|-------|
| R      | 50                                   | 290                       | 91.9                      | 2.19                               | 109.5 |
| S      | 50                                   | 298                       | 97.8                      | 1.22                               | 61.0  |

Sample S contained a lower stratum made in a laboratory pad former in the following

15 manner:

1. A carrier tissue was laid down. This material was Cellutissue 3024, an 18gsm cellulosic tissue.
2. Stratum 1 was deposited. This stratum consisted of a uniform mixture of Weyerhaeuser ND416 fiber at a weight of 86gsm, FiberVisions 1.55dpf/4mm bicomponent fiber at a

weight of 12gsm, and Stockhausen SXM70 superabsorbent polymer at a weight of 184gsm.

3. The resulting structure was then densified using a laboratory roller press. Resultant density for the structure was then 0.23g/cc.

5 4. A latex spray was then applied to the structure above stratum 1. Latex used was Air Products Airflex 124. Latex spray was a 10 percent solids mixture. This mixture also contained Aerosol OT (75 percent) surfactant added at a 0.1 percent level. The mixture sprayed resulted in a 2gsm latex solids add-on to the sample.

5. The sample was then dried/cured in an oven (Lindberg/Blue M) for 25 minutes at 150°C.

10 As seen from the data in Table 9 the sample R with y-directionally profiled lower ply has significantly higher FASE value than the control sample "S".

While the invention has been described in detail with specific reference to preferred embodiments thereof, the invention is capable of other and different embodiments, and its details are capable of modifications in various obvious respects. As  
15 would be readily apparent to those skilled in the art, variations and modifications can be affected while remaining within the spirit and scope of the invention. Accordingly, the foregoing disclosure, description and Figures are for illustrative purposes only, and do not in any way limit the invention, which is defined only by the claims.

**WHAT IS CLAIMED IS:**

- 1 1. An absorbent structure with a y-directional profile comprising one stratum or a plurality  
2 of strata, at least one stratum of which is produced by a continuous series of unit  
3 operations and which contains functional particles and has a y-directional profile  
4 comprising first and second zones disposed in contact with each other, wherein the first  
5 zone has one or more of a higher density, a higher content of functional particles and a  
6 higher basis weight than the second zone.
- 1 2. An absorbent structure with a y-directional profile comprising one stratum or a plurality  
2 of strata, and which contains functional particles and has a y-directional profile comprising  
3 first and second zones disposed in contact with each other, wherein the first zone has one  
4 or more of a higher density, a higher content of functional particles and a higher basis  
5 weight than the second zone, said structure having a FASE higher than about 50.
- 1 3. The structure of one of claims 1 or 2, wherein the first zone has a higher density and a  
2 higher basis weight than the second zone.
- 1 4. The structure of one of claims 1-3, wherein the first zone has a higher density and higher  
2 functional particle content than the second zone.
- 1 5. The structure of one of claims 1-4, wherein the first zone is disposed at the side edge of  
2 the absorbent structure.

- 1     6. The structure of one of claims 1-5, further comprising a third zone and a fourth zone,  
2         wherein the third zone has a higher density and higher content of functional particles than  
3         the second and the fourth zones.
- 1     7. The structure of one of claims 1-6 comprising a plurality of strata, wherein at least one  
2         stratum has a major surface with a surface area which is less than 80 percent of the surface  
3         area of a corresponding major surface of another stratum.
- 1     8. The structure of one of claims 1-7, wherein the y-directional profile of the structure is a  
2         result of a single stratum with a y-directional profile.
- 1     9. The structure of one of claims 1-8, wherein the y-directional profile of the structure is a  
2         result of two or more strata with y-directional profiles.
- 1     10. The structure of one of claims 1-9, wherein at least one stratum is of substantially uniform  
2         density and basis weight.
- 1     11. The structure of one of claims 1-10, wherein the structure has a z-directional profile.
- 1     12. The structure of one of the previous claims further comprising fibers.

1 13. The structure of claim 12, wherein the fibers have a water retention value of at least 80  
2 percent.

1 14. The structure of one of claims 12 and 13, wherein the fibers have a curl of at least 25  
2 percent.

1 15. The structure of one of claims 12-14, wherein the fibers comprise both natural and  
2 synthetic fibers.

1 16. The structure of one of the previous claims, further comprising a binder.

1 17. The structure of claim 16, wherein the binder is selected from the group consisting of  
2 liquid binders, including latex binders, thermoplastic powders, thermoplastic fibers,  
3 bicomponent fibers and mixtures thereof.

1 18. The structure of one of claims 16 and 17, wherein the binder is present in an amount that  
2 is between about 0.1 percent and about 10 percent by weight of said structure.

1 19. The structure of one of the previous claims having an acquisition stratum in fluid  
2 communication with the first zone, the second zone, or with both the first zone and the  
3 second zone.

1 20. The structure of claim 19, wherein the acquisition stratum comprises synthetic matrix  
2 fibers bonded with a binder, the matrix fibers having a length of from about 2 to about 15  
3 mm.

1 21. The structure of one of the previous claims, wherein the basis weight of the first zone is  
2 from 50 gsm to about 1000 gsm.

1 22. The structure of one of the previous claims, wherein the density of the first zone is from  
2 about 0.15 g/cm<sup>3</sup> to about 0.25 g/cm<sup>3</sup>.

1 23. The structure of one of the previous claims, wherein the functional particle content of the  
2 first zone is from about 10 percent to about 90 percent by weight of a superabsorbent  
3 material.

1 24. The structure of one of the previous claims, wherein the basis weight of the second zone  
2 is from about 0.1 gsm to about 800 gsm.

1 25. The structure of one of the previous claims, wherein the functional particle content in the  
2 second zone is from about 0 percent to about 70 percent.

1 26. The structure of one of claims 1 and 3-25 having a FASE higher than about 80.



1 27. The structure of one of the previous claims having wet integrity higher than about 4.0  
2 mN/gsm.

1 28. The structure of one of the previous claims having softness higher than about 8.0/J.

1 29. The structure of one of the previous claims having a pliability higher than about 70/N.

1 30. The structure of one of the previous claims, wherein the structure has been produced by  
2 a continuous series of unit operations where each stratum is formed in one unit operation  
3 from one or more materials selected from fibers, functional particles, binders, carrier tissue  
4 and additives.

1 31. A disposable absorbent article comprising:

2 (A) a liquid pervious topsheet,

3 (B) a liquid impervious backsheet,

4 (C) between the topsheet and the backsheet and in fluid communication with the  
5 topsheet an absorbent structure of one of claims 1-29, and, optionally,

6 (D) between (C) and (B) and in fluid communication with (C) a storage stratum  
7 comprising fibers and functional particles where a major surface of (C) in fluid  
8 communication with a major surface of (D) has a surface area which is less than  
9 80 percent of the surface area of a corresponding major surface of (D).

1 32. The article of claim 31, wherein (C) comprises:

- 2           (1)     a y-directionally profiled acquisition stratum; and  
3           (2)     a y-directionally profiled acquisition and storage stratum having a higher  
4           content of functional particles than that of the acquisition stratum.

1     33. The article of claim 31 or claim 32, wherein the article is an infant diaper, a training pant,  
2         an adult incontinence device, or a feminine hygiene pad.

1     34. The article of one of the claims 31-33 having a FASE of 50 or higher.

1     35. The article of claim 34 having a FASE of 80 or higher.

1     36. The article of claim 35 having a FASE of 100 or higher.

1     37. The article of claim 36 having a FASE of 180 or higher.

1     38. A process for the production of an absorbent structure with a y-directional profile  
2         comprising a plurality of strata, at least one stratum of which is produced by a series of  
3         unit operations and which contains functional particles and has a y-directional profile  
4         comprising first and second zones disposed in contact with each other, wherein the first  
5         zone has one or more of a higher density, a higher content of functional particles and a  
6         higher basis weight than the second zone, the process comprising:  
7         (1)     forming a first stratum A comprising fibers and, optionally, functional particles,  
8         and

9       (2)     forming a second stratum B comprising fibers and functional particles such, that  
10       a major surface of B is in fluid communicating contact with a major surface of A and the  
11       y-directional length of B is less than the y-directional length of A.

1     39. A process for the production of an absorbent structure with a y-directional profile  
2       comprising a plurality of strata, at least one stratum of which is produced by a series of  
3       unit operations and which contains functional particles and has a y-directional profile  
4       comprising first and second zones disposed in contact with each other, wherein the first  
5       zone has one or more of a higher density, a higher content of functional particles and a  
6       higher basis weight than the second zone, the process comprising:

7       (1)     forming a first stratum A comprising fibers and, optionally, functional particles,  
8       and

9       (2)     forming a second stratum B comprising fibers and functional particles such that  
10       first and second zones disposed in contact with each other are formed, wherein the first  
11       zone has a higher density and a higher content of functional particles than the second zone.

1     40. The process of one of claim 38 or 39, wherein strata are formed on a forming wire of an  
2       airlaid process and the first and second zones of stratum B are formed by manipulation of  
3       a vacuum under the forming wire such that there is a greater pressure differential under  
4       the first zone than under the second zone, with the consequent deposition of a greater  
5       amount of fiber and functional particles in the first zone than in the second zone.

1     41. The process of claim 38 or 39, wherein strata are formed on a forming wire of an airlaid  
2         process from fibers and functional particles distributed from a forming head and the first  
3         and second zones of stratum B are formed by partially blocking distribution into the  
4         second zone but not the first zone.

1     42. An absorbent structure produced by the process of one of claims 38-40.

FIG. 1

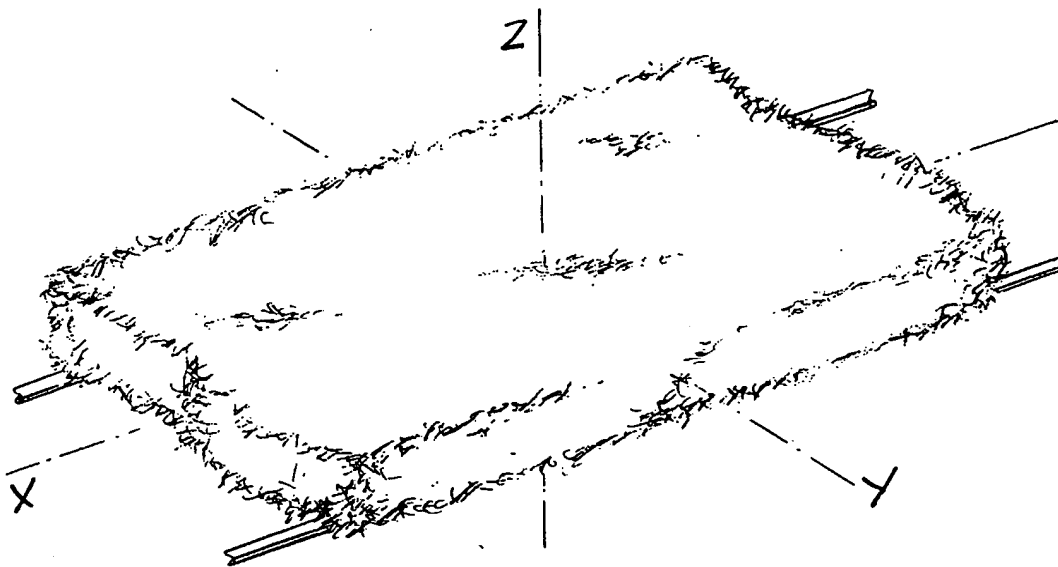


FIG. 2a  
Prior Art

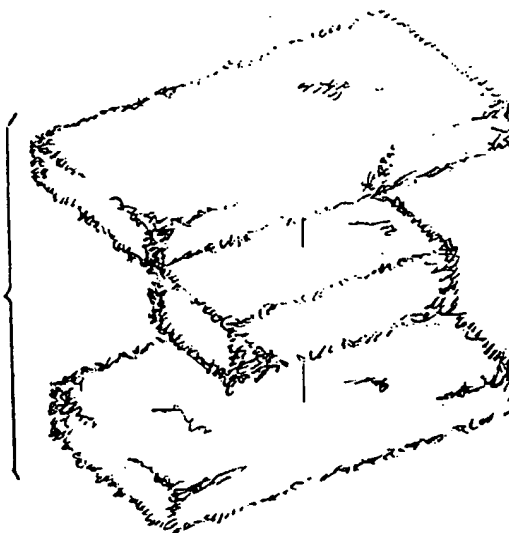
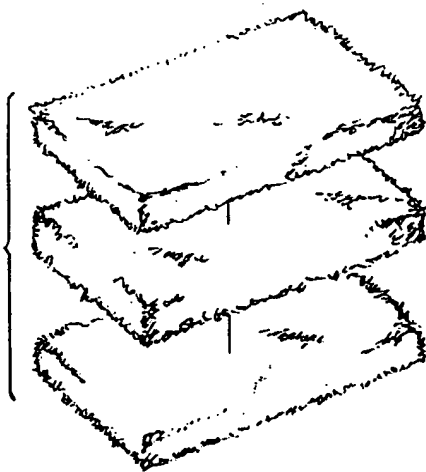


FIG. 2b

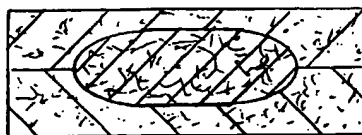


FIG. 2c

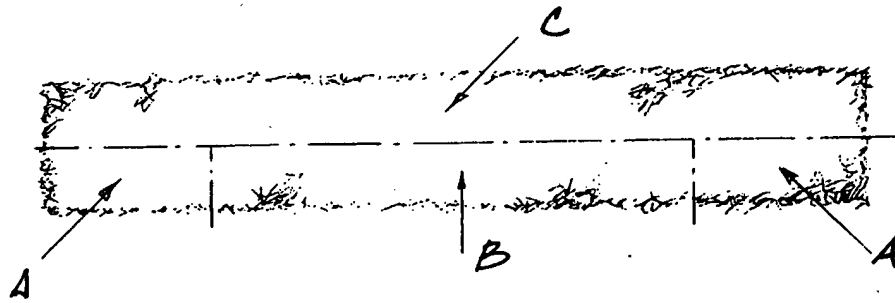


FIG. 3

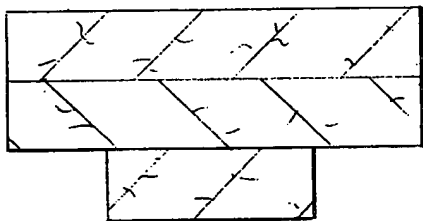


FIG. 4a

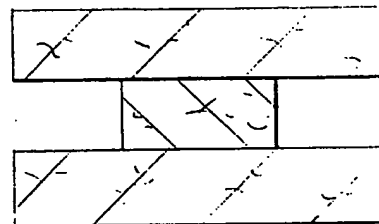


FIG. 4b

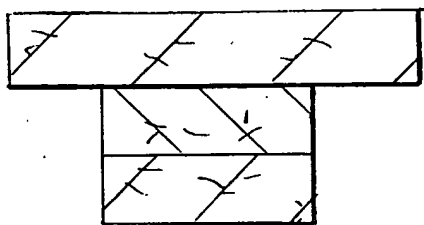


FIG. 4c

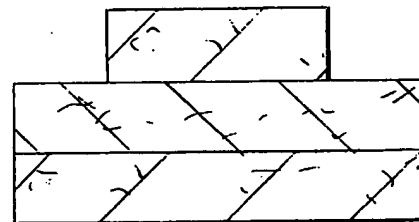


FIG. 4d

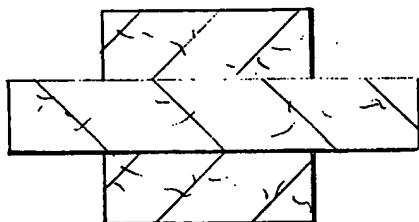


FIG. 4e

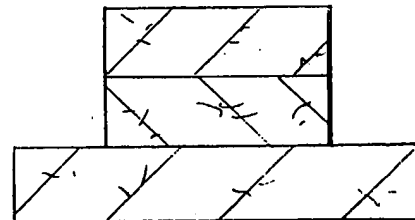


FIG. 4f

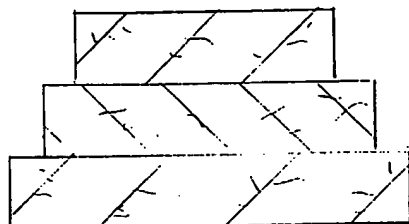


FIG. 4g

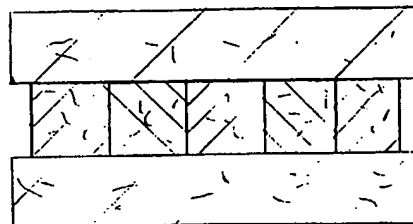


FIG. 4h

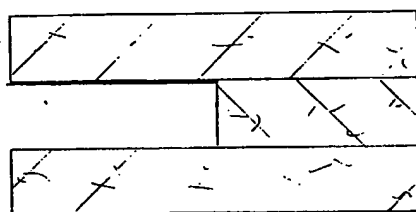


FIG. 4i

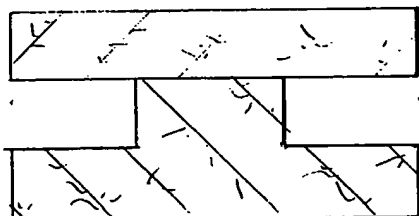


FIG. 5a

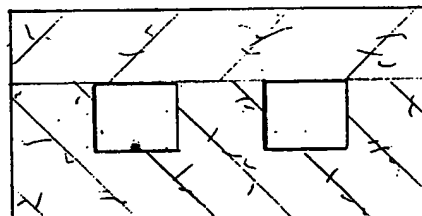


FIG. 5b

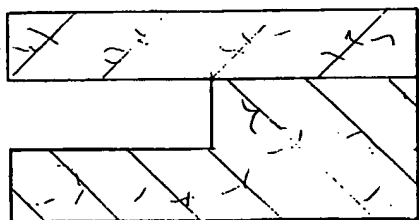


FIG. 5c

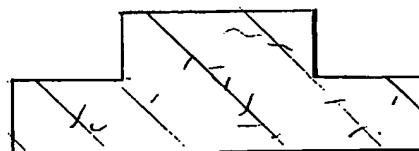


FIG. 5d

FIG. 6

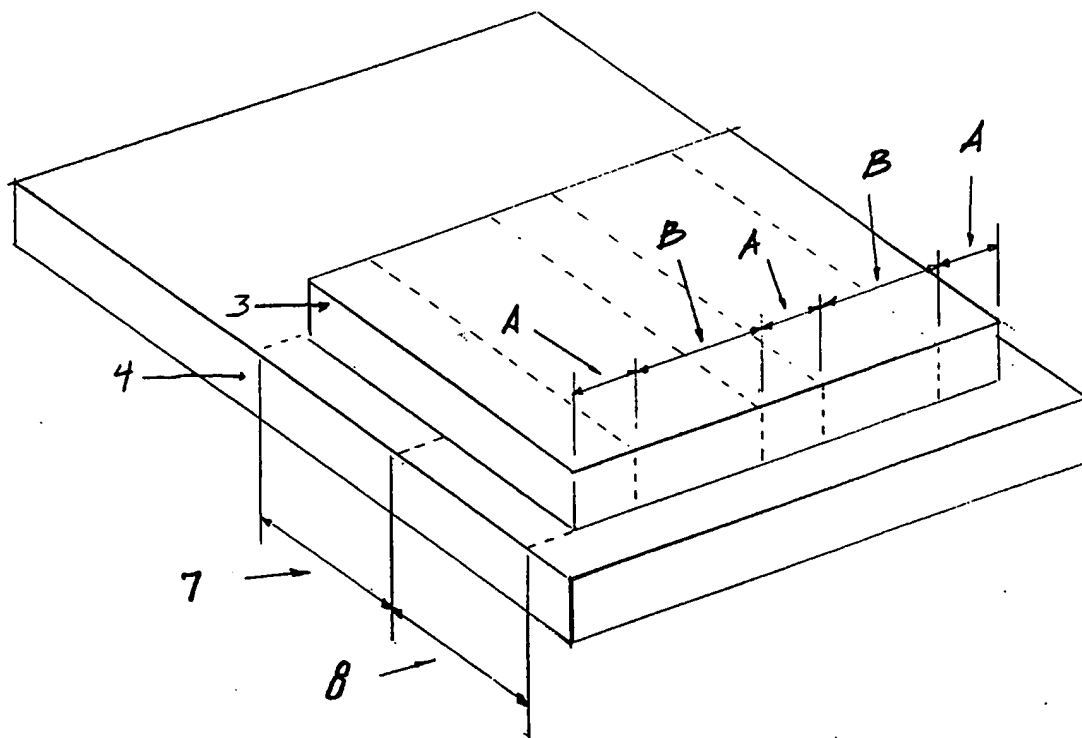
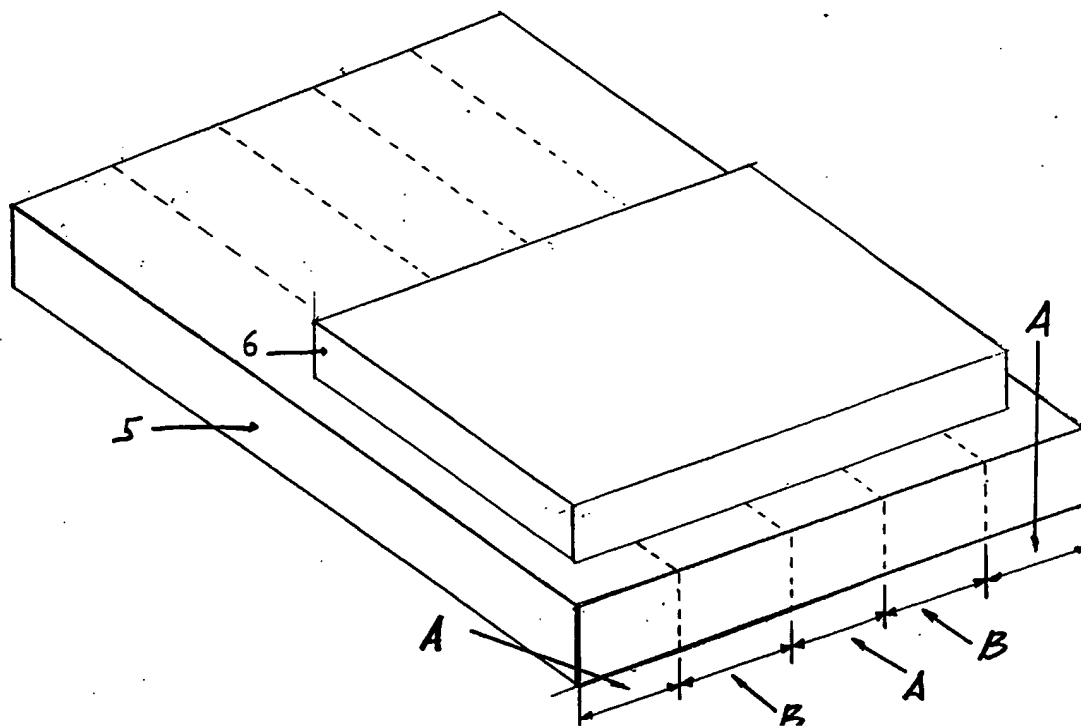


FIG. 7





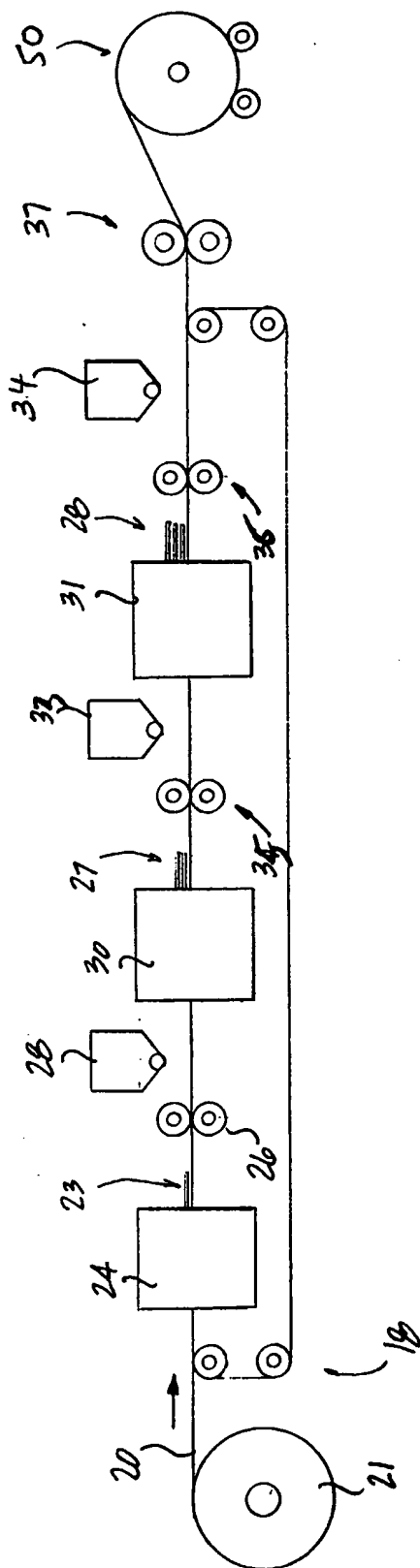
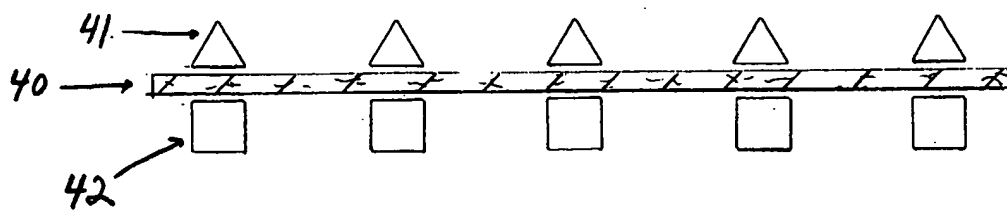
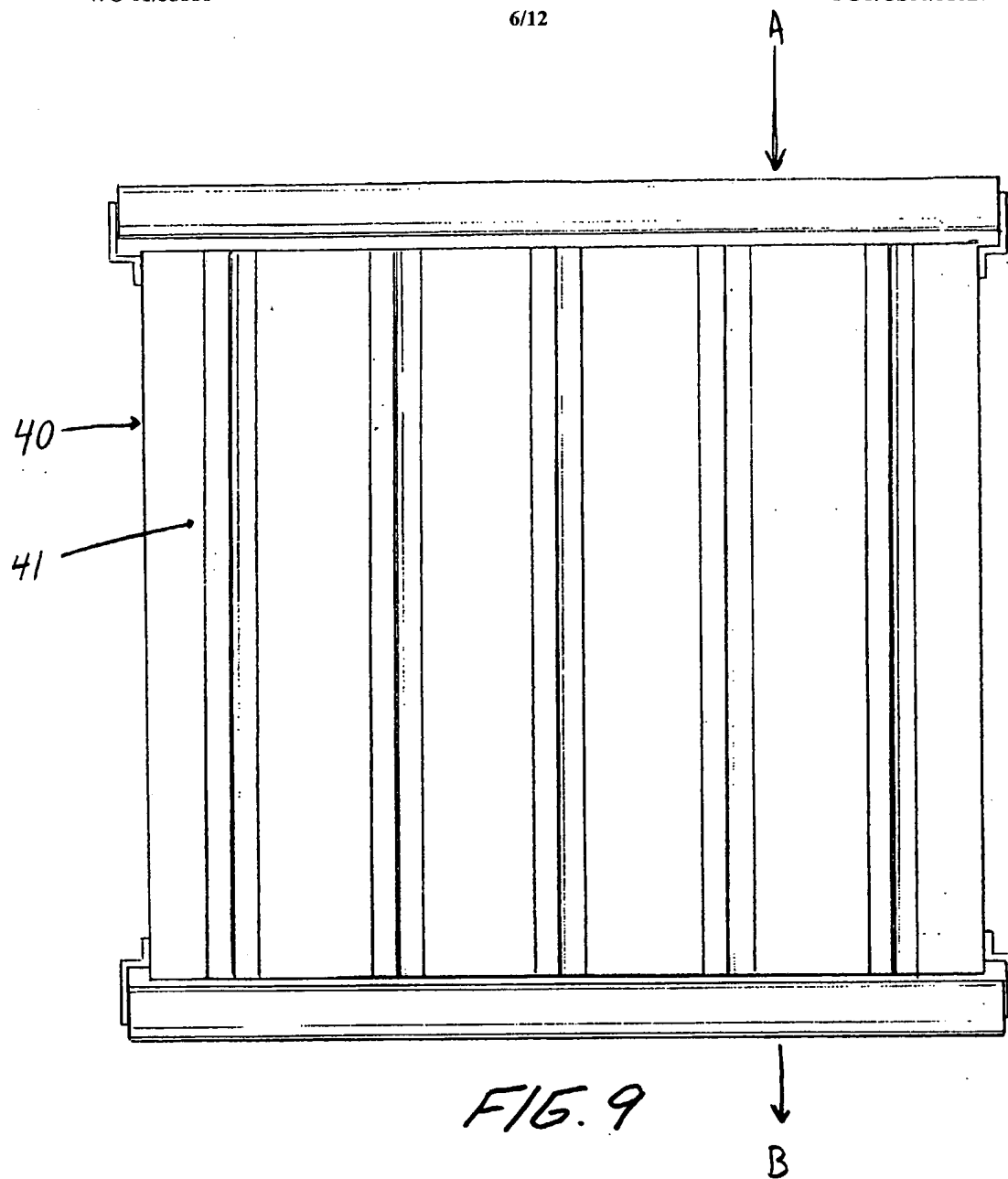


FIG. 8



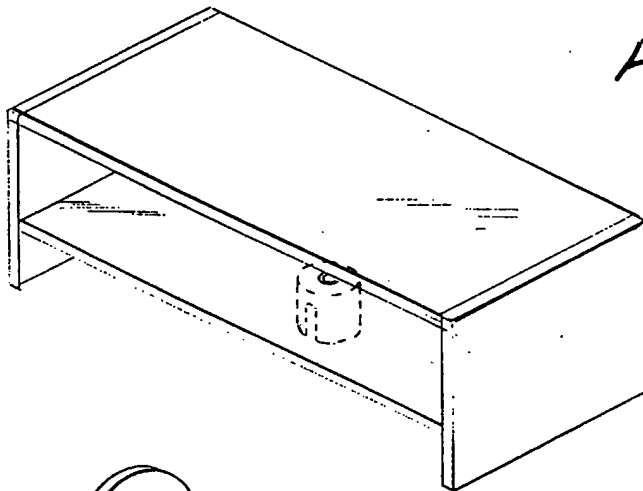


FIG. 11A

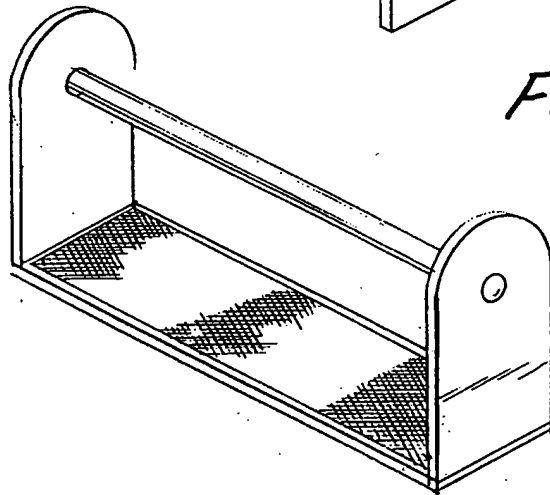


FIG. 11B

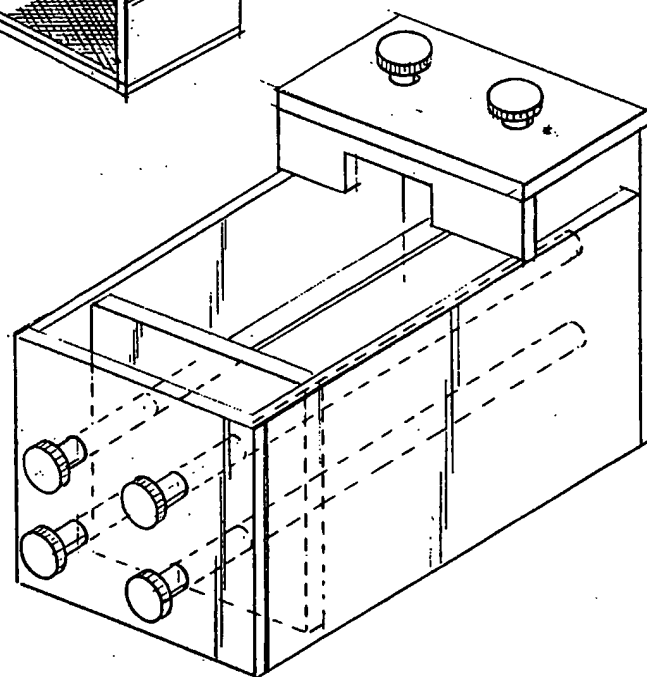


FIG. 12



FIG. 13A

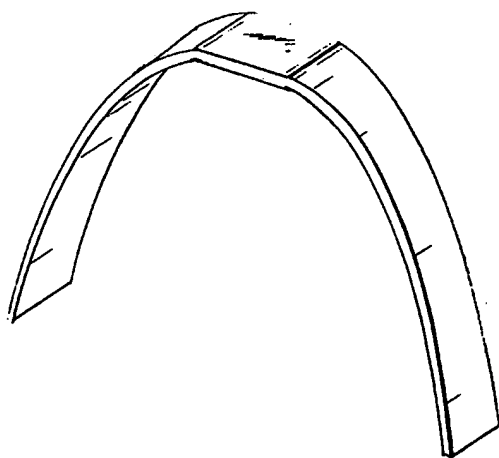


FIG. 13B

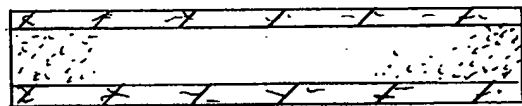


FIG. 14A

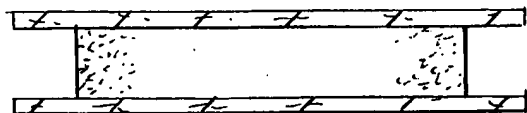


FIG. 14B

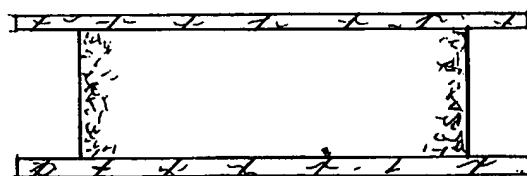


FIG. 14C

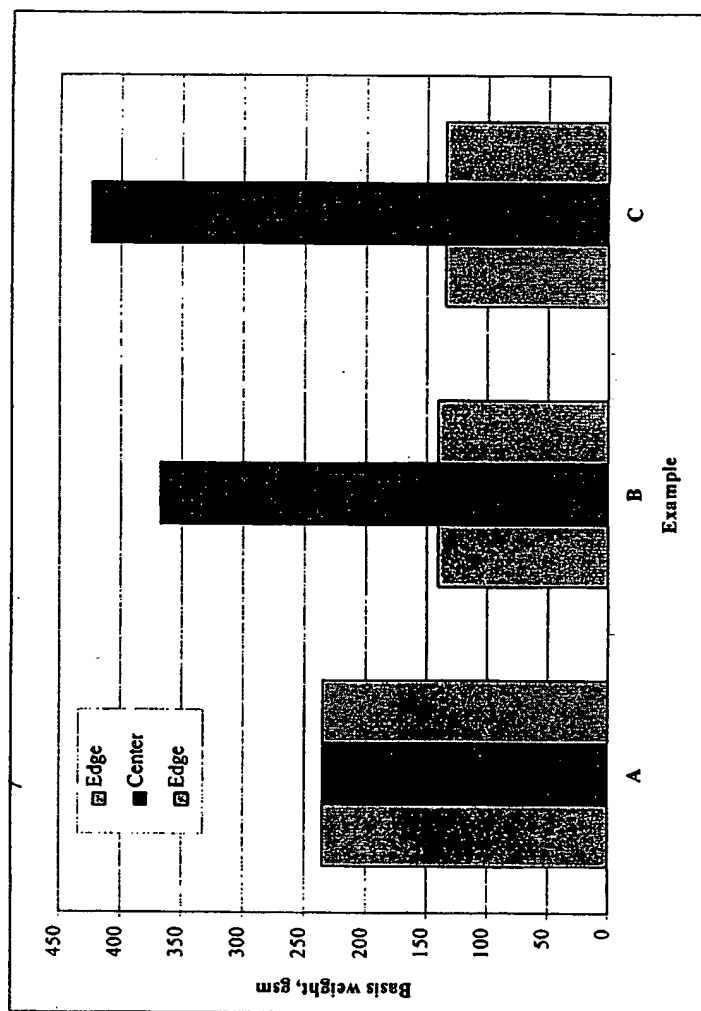


FIG. 15

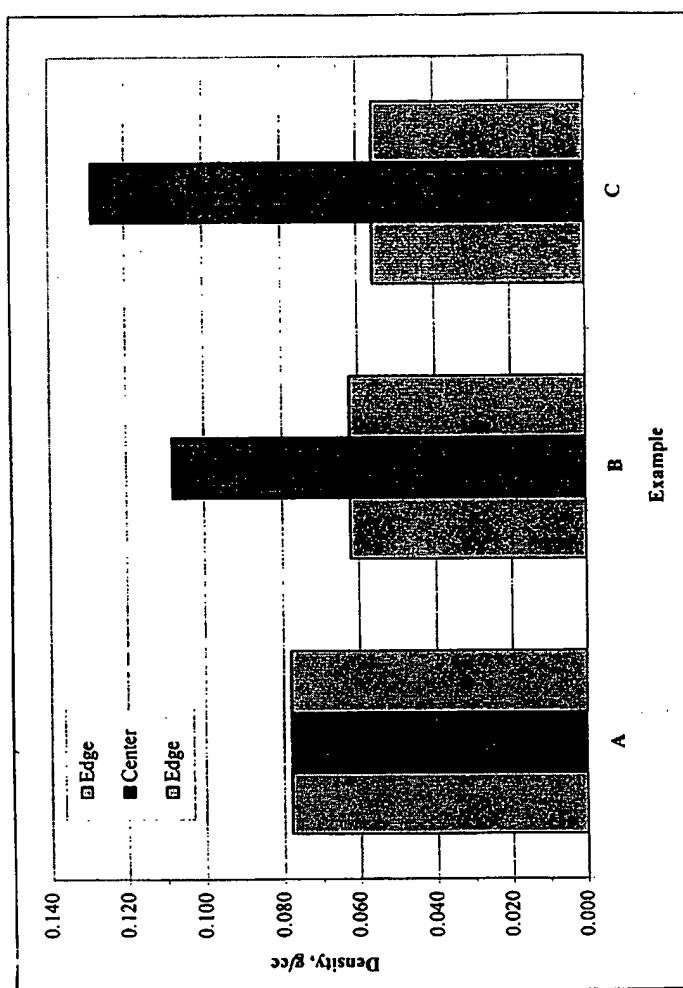


FIG. 16

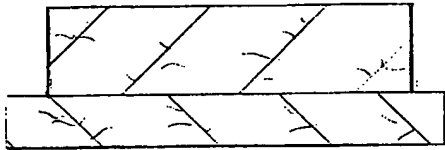


FIG. 17A

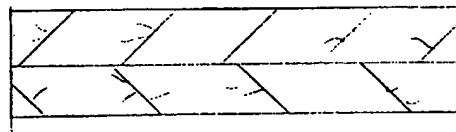


FIG. 17B

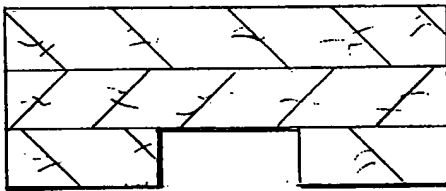


FIG. 18A

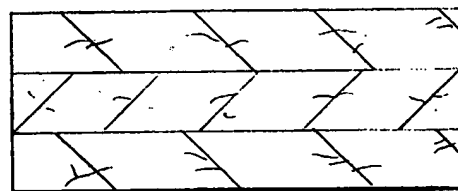


FIG. 18B

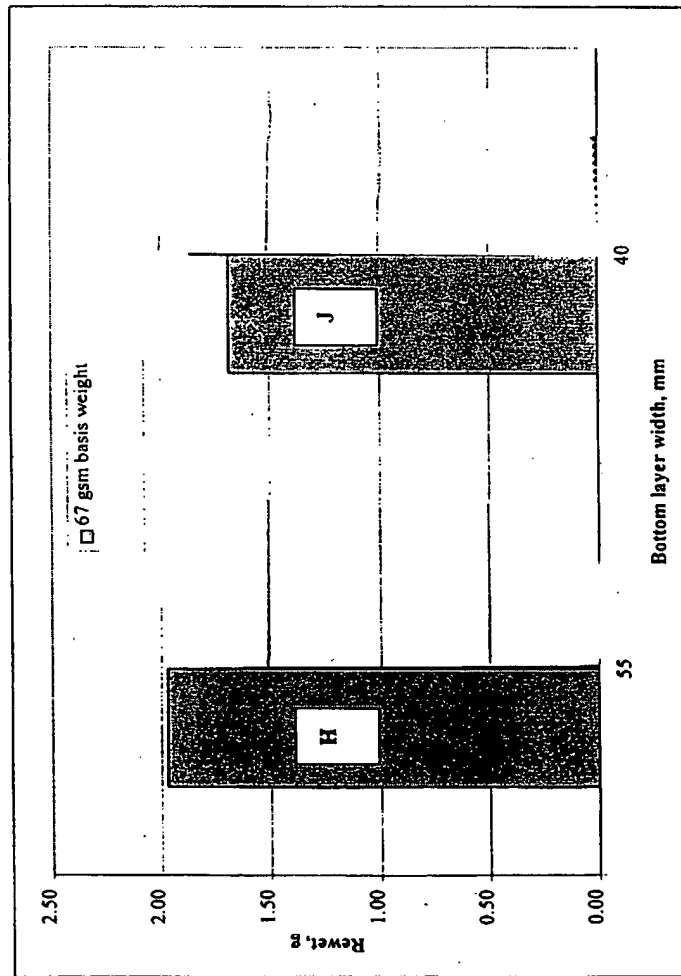


FIG. 19



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 00/31627

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 A61F13/15 D04H1/70

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61F D04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No.      |
|------------|---|----------------------------|
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|            | ---<br>-/-  |                            |

☒ Further documents are listed in the continuation of box C.

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- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search

12 February 2001

Date of mailing of the international search report

23/02/2001

Name and mailing address of the ISA

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Joly, F

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In International Application No.  
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II International Application No  
PCT/US 00/31627

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PCT/US 00/31627

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In International Application No  
PCT/US 00/31627

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)   | Publication<br>date  |
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